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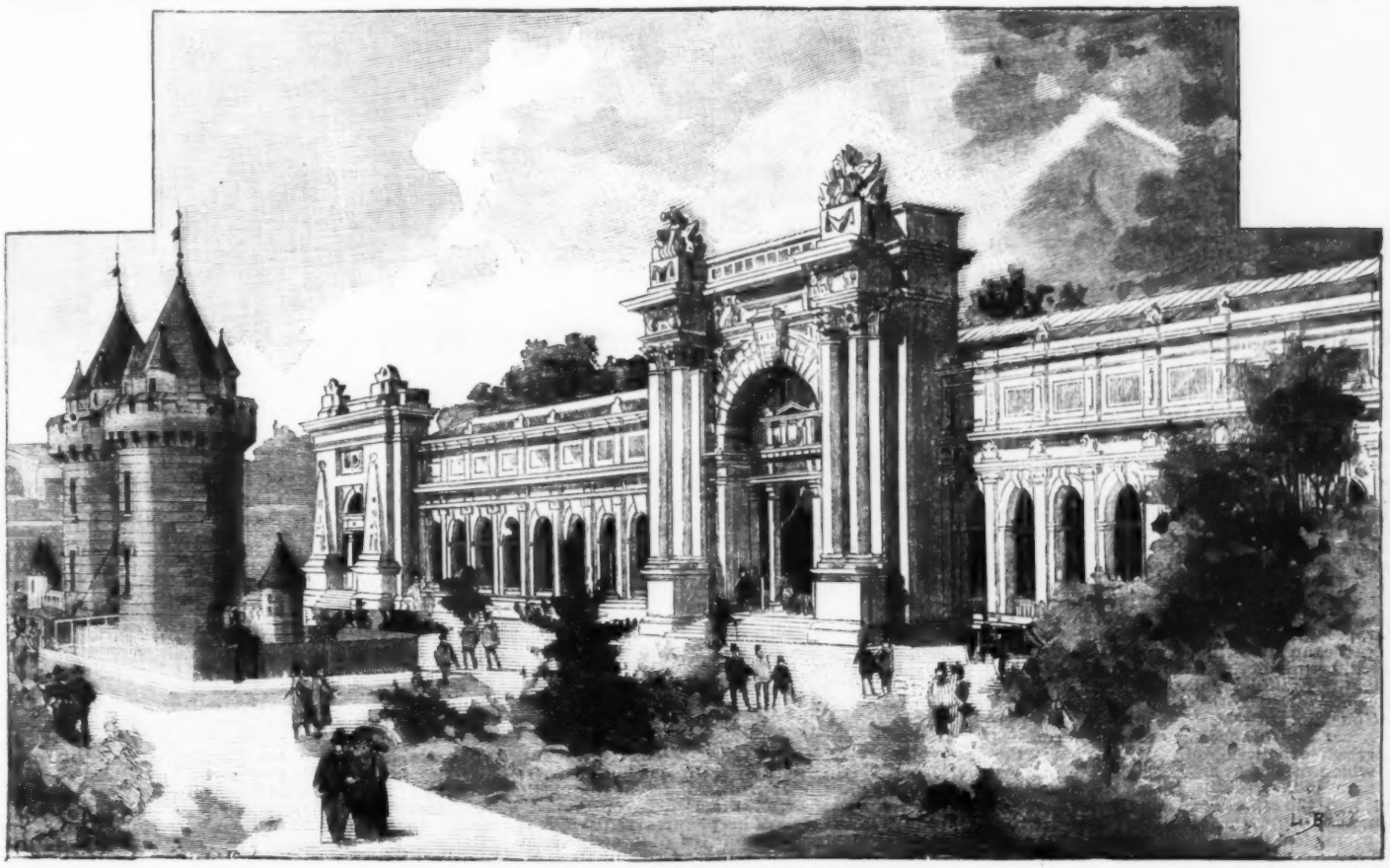


EXPOSITION OF THE WAR DEPARTMENT.

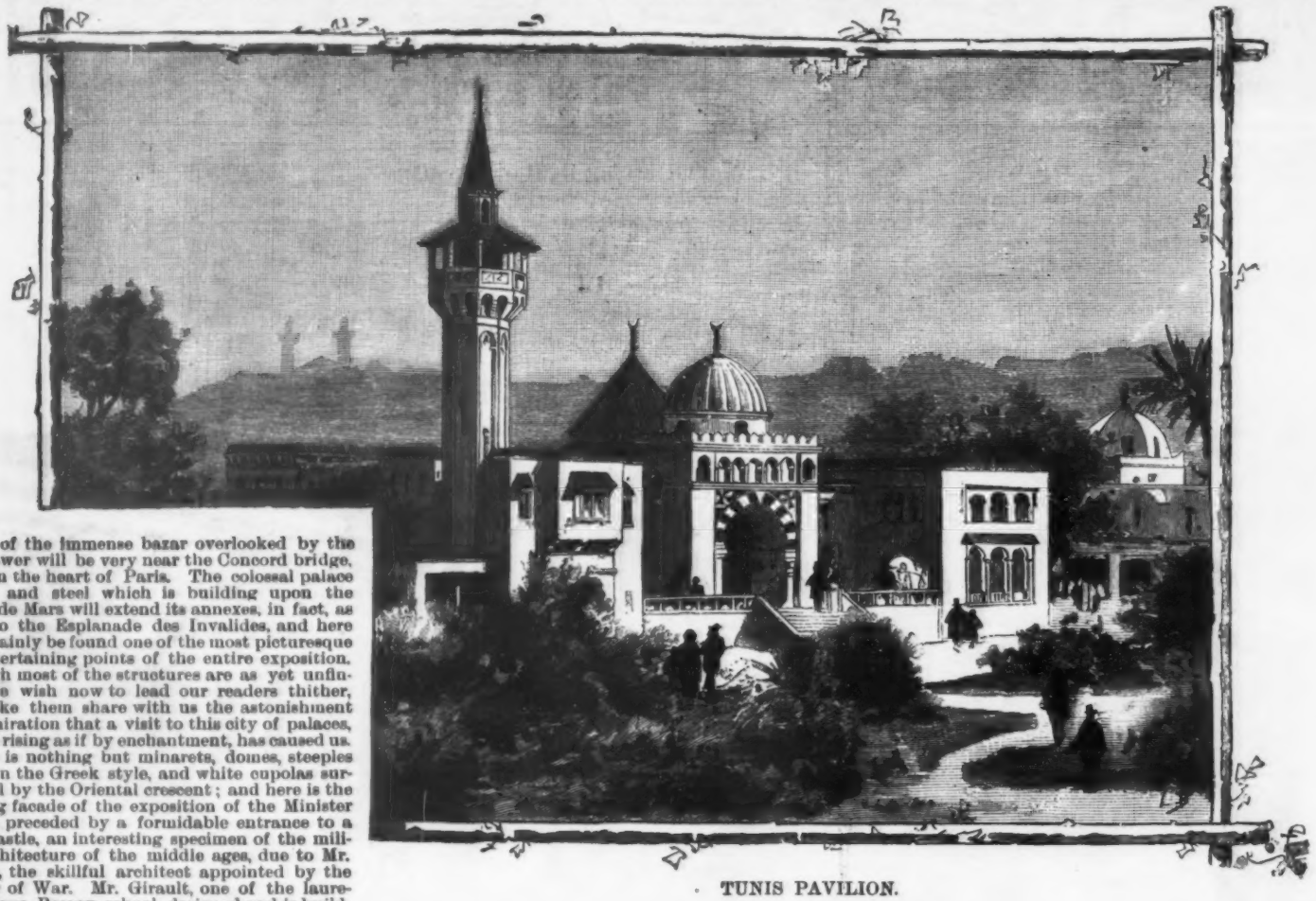
THE PARIS EXPOSITION OF 1889—GENERAL VIEW.

THE FRENCH EXPOSITION OF 1889 AT THE ESPLANADE DES INVALIDES.

ONE of the great novelties of the future exposition—and this will certainly be obvious to Parisians—will consist in the fact that one of the monumental entrances of the immense bazar overlooked by the Eiffel tower will be very near the Concord bridge, nearly in the heart of Paris. The colossal palace of iron and steel which is building upon the Champ de Mars will extend its annexes, in fact, as far as to the Esplanade des Invalides, and here will certainly be found one of the most picturesque and entertaining points of the entire exposition. Although most of the structures are as yet unfinished, we wish now to lead our readers thither, and make them share with us the astonishment and admiration that a visit to this city of palaces, which is rising as if by enchantment, has caused us.

There is nothing but minarets, domes, steeples shaped in the Greek style, and white cupolas surmounted by the Oriental crescent; and here is the imposing facade of the exposition of the Minister of War, preceded by a formidable entrance to a feudal castle, an interesting specimen of the military architecture of the middle ages, due to Mr. Walrein, the skillful architect appointed by the Minister of War. Mr. Girault, one of the laureates of our Roman school, designed and is building the pavilion of hygiene, Mr. Ballu that of the Algerian exposition, and Mr. Sauvestre the central pavilion of the French colonies. Further along, there is an Indian temple, then a dwelling like those conceded to the colonists in our New Caledonian possessions, and, above this picturesque decoration, rises, nearly completed, the elegant minaret of the Coubba of Sidi-ben-Avouz, which overlooks the whole of the Tunisian section. This latter, seeing the peculiar interest taken in our new protectorate of Africa, will certainly be one of the principal attractions of the Exposition of the Invalides. The structures of the Tunisian section, the heavy work upon which is now finished, are the ones that, for the moment, give the best idea of what the picturesque part of the exposition will be. Mr. Henri Saladin is the architect of it. Prepared for this work by a trip that he has given an account of in the *Tour du Monde*, in conjunction with Professor Cognat, of the College of France, he has united in the style of his picturesque pavilion the most delightful specimens of Oriental architecture. The arcades of the front were suggested by those of Bardo, the central dome is an exact reproduction of the Mikrab of the mosque of Kerouan, the loggia is that of a Tunisian house. There will be here some souks or covered bazars, an interior court with a pavement of colored tiles, and a cafe is going up under the shade of a group of trees. And all this will be filled at the proper time with the riches of Tunis—fabrics, carpets, ceramics, works of art, and, finally, with all the surprises that could be expected from the organizing zeal and talent with which Mr. Sauson, Commissary General of the Tunisian government, is endowed.

Let us not leave the Esplanade des Invalides without mention also of the Tonquin village that is to be built there, the English dairies, the Dutch bakeries, and especially the phenomena of All Paris, which we



TUNIS PAVILION.

CENTRAL PAVILION, FRENCH COLONIES.

THE PARIS EXPOSITION OF 1889.

have had the good fortune to get a glimpse of. Mr. Castellani's brush has brought hither the entire Place de l'Opera, with its marble building, its tall houses, the groups of trees of the boulevards, the distant blues of the avenues, and, under the glowing sun with which he has illuminated his work, nearly a thousand persons are coming and going. There are nearly a thousand portraits of natural size—All Paris, all those who count, all those who are spoken of. There will be here . . . . but why unveil one of the prettiest surprises that the exposition reserves for us? Mr. Castellani can calculate upon success. It is not only All Paris that will visit him, but also all those who care to see the exposition.—*Le Monde Illustre.*

SKILL AND ART IN THE HEATHEN ERA.*

By J. T. FANNING.

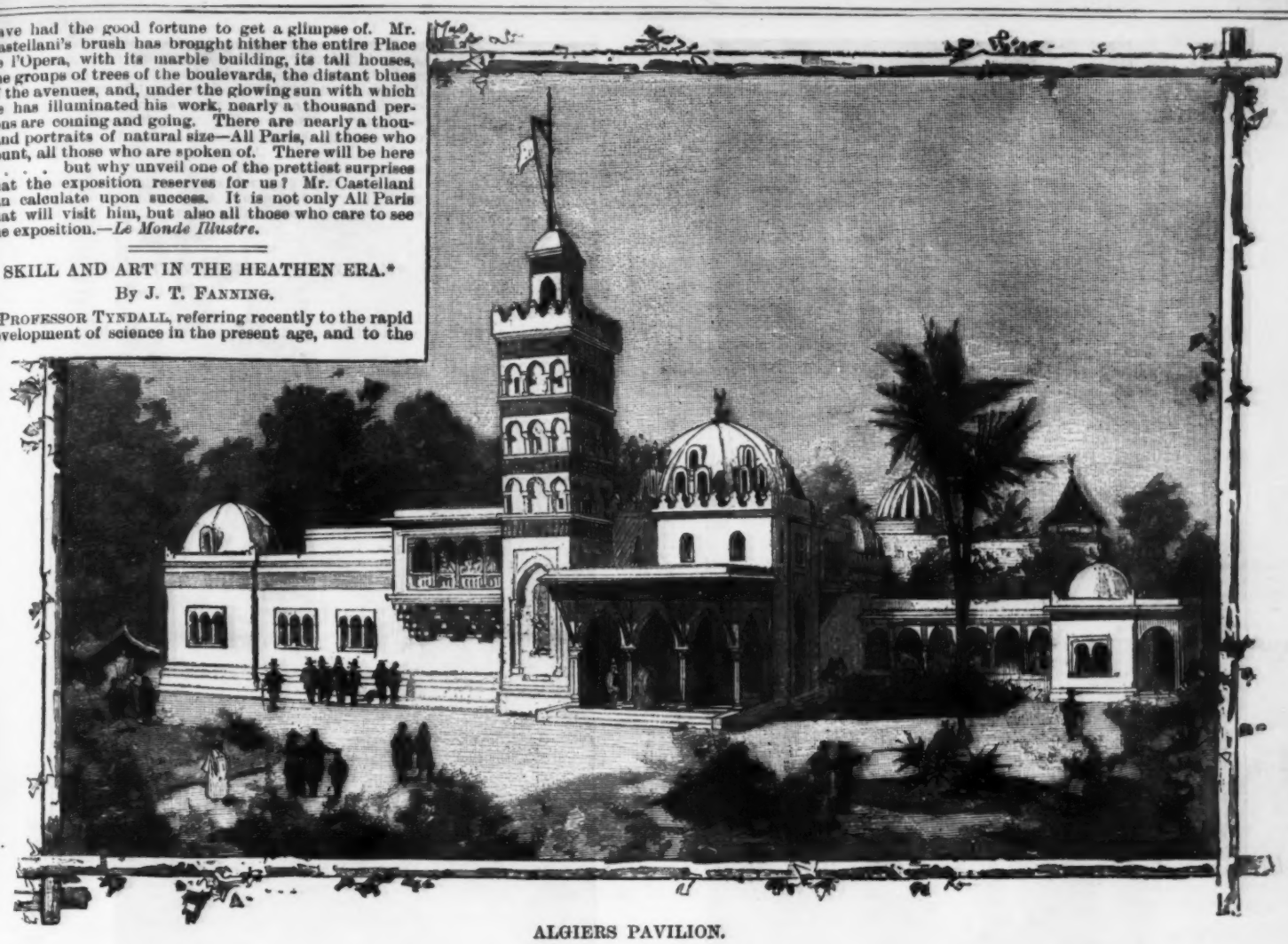
PROFESSOR TYNDALL, referring recently to the rapid development of science in the present age, and to the increasing public interest in its results, spoke also of science as being now the supreme interest of civilization. We observe its influence working in public school and collegiate institution, and already it threatens to overshadow the long established classical regime in the universities.

In the department of building, science has given rapid transference of thought and commands from office to workshop and quarry, rapid and easy transportations of materials and rapid accumulations of mechanics and supplies wherever great structures are to be erected. If canals, aqueducts, bridges or halls of legislation are now to be constructed, science has shown how to increase the results of the manual labor in them a hundredfold, and it has so multiplied constructive possibilities that we contrast with pride our splendid modern facilities with those of the workmen of old, who toilfully dug with rude utensils such ditches as our steam shovels excavate at surprising rate, or who slowly rolled up long inclines such blocks of stone as our hoisting engines quickly whisk up three, five, or seven stories height.

While the results of science are of general interest and accrue to the general benefit, there are none who more fully appreciate the scientific development of our time, with its increase of opportunity and power, than engineers and architects, its devotees, for they, chiefly, design and direct the construction of the notable works of the age, which present the highest applications of scientific skill, and whether these works be revetment, aqueduct, truss, or temple, their acknowledged successes are measured, more than all else, by the influence of the skill and art that pervades them.

Modern buildings are in harmony with the advanced stage of modern civilization, and so public works in each generation, and we might say in each city and

* Read before the Minneapolis Society of Civil Engineers.



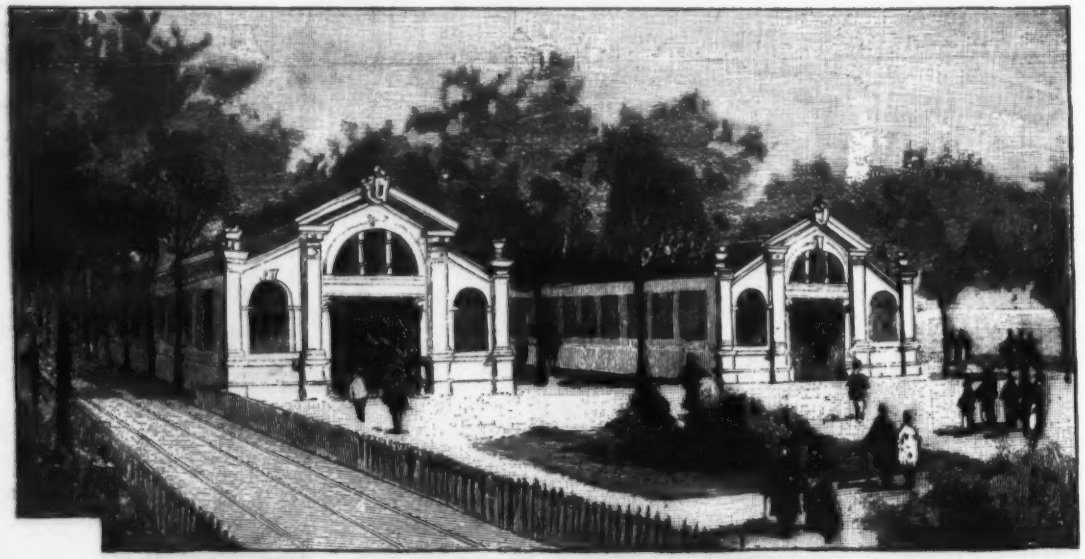
ALGIERS PAVILION.

EXPOSITION OF HYGIENE.

THE PARIS EXPOSITION OF 1889.

THE TUNIS SOUK.

TONQUIN VILLAGE.



ENTRANCE TO THE AGRICULTURAL GALLERIES.

BUILDING OF THE COLONIES CEDED TO NEW CALEDONIA.

THE PARIS EXPOSITION OF 1889.

PAVILION OF COCHIN CHINA AND ANAM.

In prosecuting our studies of the ancient people and their works, it is convenient to arrange the gathered facts first in inverse chronological order, as in a lengthy panorama, and glance from the modern standpoint backward, till the view is lost in the distant perspective, and then with the advantage of more familiarity to reclassify in true order of sequence. Ancient skill is more ancient in origin than art, and has in much less degree attracted the attention of historical writers, and for our knowledge of it we are dependent more on the remains of ancient works than upon written history. Skill, as well as art, has had its culminating periods of progress and then its periods of neglect, and these have in general been introductory to and contemporaneous with advancements and declines of art. Its periods of great progress may be broadly classified, as is usual with art, into *ancient*, *mediæval*, and *modern*. Ancient skill and art had their full measure of glory and came to their decline under heathen patronage before mediæval skill and art felt the inspiration of Christian influence.

The student of ancient history who would commence his studies with the character of the people and works of skill at the early dawn of civilization, and trace them in order of sequence to the middle age, is surprised at the outset to discover that there are few traces of reliable ancient history in existence antedating the classic age, other than that wrought by bone and sinew into enduring canals and tombs and temples.

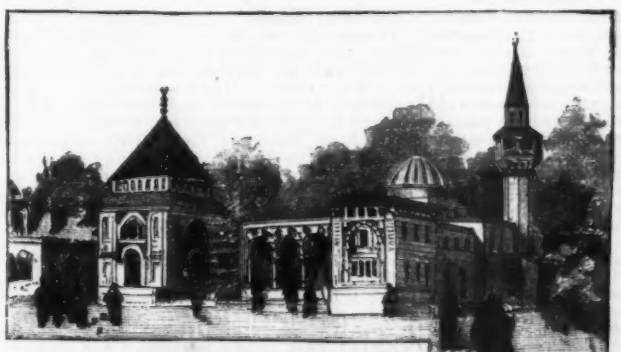
village, are and have been constructive expressions of the civilization of their time and locality. They are a portion of Nature's historical record of the necessities, desires, and mental status of the people who projected them, as well as of the acquirements of the architectural engineers who designed them.

While the public works of the different eras may not claim our attention as models for modern reproduction, they offer a line of study of most intense interest in the unimpeachable history which they present of the advancing or retrograding stages in evolutions of national thoughts along the varied ethnological successions, and teach us of the origin of the inherited skill and artistic development which our era is not too modest to claim. In a comprehensive view along the structural eras of the past, the lapse of time covered by structural history gives us power to note the characteristic features of the early works, and through them to individualize the ancient workers, and to study their distinctive traits as shepherds, invaders, migrators, traders, and as artisans or idolators.

Thus through the aid of such bass-reliefs, intensified by time, we analyze the peculiarities of the Egyptians, Hebrews, or Greeks, as nations, as through familiarity we are enabled to perceive in clear relief the personal characteristics of our individual neighbors and intimate friends.

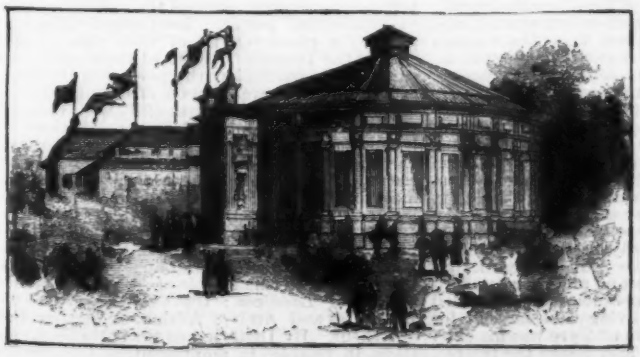
Individuality in nations has a broad significance, and its study in the ancients will not only add interest to, but help us to understand more thoroughly, our own distinctive characteristics, our precious inheritance of mental power, with mechanical and technical skill, scientific acquirement, and artistic perception. And there is an ever-recurring interest in comparisons of the skill, talent, and genius of the moderns with the like faculties of the earliest people of whom we have any history or tradition, who fulfilled their political destiny several thousand years ago.

Were it not that certain royal constructions of the ancients endure until to-day, the records of ancient peoples, once powerful in influence and in deeds, would long ago have passed into tradition and myth. Starting in ancient historical research from the classic age and classic lands, the student is led backward step by step toward the East, and finds himself guided by footprints of a host of noble seekers after knowledge—Pythagoras, Solon, Strabo, Tacitus, Archimedes, and many others who journeyed in the early days down into Egypt, a birthplace of skill, science, and art, to drink there their fill from an ancient fountain of knowledge.



TUNIS PAVILION—SIDE.

KANAKA HUTS.



PANORAMA OF PARIS.

INDIAN TEMPLE.

THE PARIS EXPOSITION OF 1889.

In Egypt the philosophers early learned to distinguish the constellations, to foretell eclipses, and to reckon time; to divide and compute geometrical areas and to survey the lands after the inundations. There the builders early learned to quarry and to hew stones, and there the agriculturists early learned to irrigate the lands which the rains of heaven rarely fell upon. It is natural that in a rainless country beneath a tropical sun, the earliest development of skill should be in the practice of irrigation, and tradition relates that hydraulic works were commenced almost immediately upon the arrival of the Hamitic colony of Mizraim in Egypt. Through the agricultural necessities and opportunities on the plain, this people became practical hydraulicians, and developed the instincts that led to the construction of those vast irrigation works which, together with lesser works of recent date, are this day watering Egypt, Chaldea, and India. Reference to a few only of their great works will be necessary to show to what skill they attained, and these references may be chiefly to hydraulic works, because they are less familiarly known to students of art literature. From the very border of traditionary history comes the story that Menes, whom the priests named to Herodotus as the head of the first great dynasty of Egypt, diverted the mighty Nile from its course and established his palace and the city of Memphis over its former bed, where they became the center of rule of the great Memphian kingdom before the foundations of the first pyramids were laid. At a later period, when Sesostris, a powerful monarch, returned from his successful Asiatic campaign with a horde of captives and with spoils from every kingdom between the Persian Gulf and the Euxine, he began a systematic irrigation of the valley of Egypt, and dug numerous watercourses, intersecting the whole plain. To enhance the usefulness of these and additional canals, Mœris is said to have planned and completed, four thousand years ago, the immense reservoir that now bears his name, and to have dug a canal from the upper river to the newly formed lake to retain the Nile floods for the irrigation of the lower valley of Egypt. It is claimed to have had originally a circumference of four hundred and fifty miles. Rising out of the basin now exists the great pyramidal tomb of Mœris. Lake Mareotis also, and other great reservoirs, were improved, excavated, or brought into use for storage of the Nile floods, so that each season of irrigation might be prolonged and the agricultural products of the country multiplied.

Pharaoh Necho, six hundred years before our Christian era, constructed a maritime isthmus canal, extending from the Nile near Heliopolis to the Bitter Lake Basin, through which the recently excavated isthmus canal passes, and thence to the Gulf of Suez at the head of the Red Sea. The breadth of this ancient ship canal is given as one hundred feet, and depth as forty feet, and its length exceeded that of the modern isthmus canal. Strabo states that ships of the largest size could navigate it. This canal was in use five hundred years, until after the time of the Ptolemies, and then neglected until it was partially filled by drifting sands. Twelve hundred years after its first construction it was reopened by the Caliph Omar, and continued in use one hundred and twenty years, until the destruction of Alexandria. Recently it was again opened in part, to lead potable waters to laborers on the modern Suez canal. At Cairo there is an aqueduct three thousand years old, and Savery, a French explorer, discovered great reservoirs hewn in the rocks upon the hills in different parts of Egypt, from which water once flowed to irrigate the land. While these remarkable hydraulic works in Egypt were being developed, the kings, in succession, were building their mighty pyramidal monuments and setting their lofty obelisks, excavating their wonderful rock temples and constructing massive palaces and places of worship which have served for a basis of later classic skill and art. The beautiful temple of Tentyra is now beheld by the traveler who ascends the Nile as one of the legacies of ancient skill, and has ever proved a monument of wonder and delight. A traveler of renown, standing beneath its portico, was so enraptured as to exclaim that he really was in the sanctum of arts and sciences.

The Serapeum at Memphis was a magnificent group of temples, approached from the city through an avenue of sphinxes. The subterranean tombs of these temples are remarkable in extent, and contained enormous sarcophagi of granite, sometimes twelve feet high and fifteen feet long, and weighing more than one hundred tons each. The colossal statues of Rameses II. were carved of syenitic granite, above seventy feet in height, and were set up in ancient Memphis. One of these exists as the fallen colossus. The Egyptian Labyrinth, erected near Lake Mœris, about 1800 B. C., contained twelve palaces under one roof, and is said to have had a peristyle court and three thousand chambers, and many vaulted passages. It was constructed of polished stone, with pillars and columns of granite and porphyry. It is said that the opening and closing of its doors echoed like the reverberations of thunder. Herodotus and Strabo visited this palace and found it difficult to explore its labyrinthian halls without a guide.

In the absence of trustworthy written records of the ancient peoples, the history of their migrations is obscure, and the conjectures respecting them are conflicting among the best authorities; nevertheless, there is very convincing mechanical evidence in the ruins of vast hydraulic works still observable far to the eastward that the early people of Mizraim prospered and multiplied in a degree unapproached by other descendants of Noah, and that, in consequence of their prolific growth from their Egyptian base, they, in the far distant past, advanced like an inundation, eastward along the tropic of Cancer, across Arabia and Chaldea, past the Persian Gulf, and down into the peninsulas, possessing the coast along the Indian Ocean to the northeastern shore of India. If search is made for their hydraulic skill in Chaldea, there may be observed in the extensive plain where the waters of the Euphrates and Tigris meet, traces of great reservoirs and canals. There the floods were stored for irrigation of the plain, as the earlier Cushites had stored the waters of the Nile.

When Babylon of old became a capital on the great river, the Chaldeans taught her Shemitic rulers to protect the city from inundations by diverting the surplus water from its natural channel into a new course and into storage basins. Our Hebrew record relates that Cyrus, when afterward investing Babylon, deepened this same diversion channel and dried the bed of the Euphrates, and thus admitted his army within the walls of the doomed city while Belshazzar and his thousand princes were stupefied with feasting and revelry.

Search for their hydraulic skill in India also discovers immense bunds, or storage reservoirs, constructed before the period of written history, and they may be counted more than one hundred thousand in number, many of them built most substantially of stone. Some of these masonary dams still retain ruins of their ancient temples that crowned them. In Ceylon may be cited a great dam extending across a valley, which is said to be fifteen miles in length, and is faced with huge blocks of stone well cemented together, and originally confined a lake of great extent. In India we find also the great monuments, the obelisks, and the rock temples, such as are more familiarly known to European travelers in Egypt; and the great subterranean temples at Elephanta, Ellora, Salsette, and Canara have been explored, and the similarity of their sculptured walls and pillars to those of Egypt discovered. It has been estimated that it would require the labor of forty thousand men forty years to excavate and carve the temple at Salsette by the supposed methods originally employed.

It may be asked why these far-off works are attributed to colonists of Egyptian origin, since they are of a prehistoric age. Shrewd ethnologists have observed that the early independent colonies springing, as the Hebrew record states, respectively from Shem, Ham, and Japhet, developed each peculiarly distinctive characteristics, practical, artistical, and intellectual as well as moral. The Hamites, whose works we have been referring to, and whom the ethnologists term Turanians, have especial instincts and talents for irrigation and building, and wherever they wandered they fixed indelibly their mark of reservoir and canal, and tunnel, and huge structures of enduring masonry. The Semites and the Aryans and Celts, descendants of Shem and Japhet, never did, and possibly because of political and religious influences never could, build such vast and enduring structures. If we recognize these peculiarities of the original colonies as separated in early post-diluvian times, it will add intensely to the interest of the study of their habits, while still remaining and diverging as distinct races, and we shall watch with interest the results as affecting skill and art, where they are again brought into close intercourse many centuries later in the all-absorbing Roman empire.

It was these Turanians of the early Memphian kingdom who, under the influence of idolatrous worship and absolute monarchical rule, first became intuitive and mighty builders, building, as it were, for eternity, the most mighty monuments of any age, that still remain, and so old that we cannot with certainty fix their dates within a thousand years. The sublime structures themselves, with their hieroglyphic inscriptions, are the only records remaining of the ancient people who first invented science and art.

These mechanical instincts, first developed in the Memphian kingdom, again assert themselves in the wonderful temples and palaces of the Thebian kingdom in Egypt. There the arts of quarrying, stone cutting, and symbolic sculpture, and the skill to transport and handle heavy weights, were brought to great perfection, and there we may find long and deep stone lintels weighing one and two hundred tons each, placed high upon pillars, or as roofings of apartments, and there we may find whole structures built of massive blocks of stone, such as modern masons' riggings are by no means adapted to handle. Those ancient mechanics could square stone with the most scrupulous accuracy, and polish their faces to surfaces like glass, and set them with the utmost precision, and those same old workmen could also excavate in solid ledge such palaces or temples as their kings or priests required, leaving portal and pillar and partition in place, enlivened with emblematic sculptures; or they could, when their religion demanded, chisel a hill of rock into a gigantic sphinx with a temple between its paws, or into a massive tomb, moulding the everlasting hill into everlasting art.

Searching again for the colonial influence of this building instinct, we find that the early Phœnicians displayed mechanical skill not unworthy an offspring of Egypt.

Some eminent philologists, noting that the language of the Phœnicians has been within the historic period more closely allied to the Assyrian than the Egyptian tongue, have claimed them to be of Semitic origin. The evidences of their mechanical instincts, and of their moral instincts, very strongly indicate them, or otherwise an influential infusion among them, to be of Turanian origin. Moses calls them Canaanites. Good authorities, on the basis of their own traditions, claim them to have been a colony from the vicinity of the Persian Gulf, a land undoubtedly held by the Hamites at an early period. Whatever their origin, the Egyptian mechanical influence asserts itself strongly in their public works, the ruins of which still indicate massiveness.

Strabo says that the walls of Tyre in Phœnicia were one hundred and fifty feet in height, and were built of massive blocks of stone, and that the remains of its aqueduct are of the most solid construction.

Also in Carthage, a daughter of Tyre, founded nearly three thousand years ago, traces of sewers remain, and great reservoirs are now to be seen near the western walls. Cressy says the ruins of the Carthaginian aqueduct may be traced a distance of fifty miles, including a thousand arches of beautiful masonry, which are upward of one hundred feet in height.

In Syracuse, which we remember as the birthplace of Archimedes, that had 1,800,000 inhabitants when besieged by Marcellus (B. C. 212), there is now to be seen a great reservoir cut out of solid rock. There a tunneled conduit extends from Syracuse under the sea to the island of Ortygia, which we may justly regard as a remarkable example of ancient subaqueous engineering.

That the Hamitic people still excelled in skill in Solomon's time is evident by the biblical record that Solomon sent to Egypt "a thousand and four hundred chariots" at one time; and when Solomon had decided to build a great temple to the living God, he sent for Phœnician workmen, and Hiram of Tyre was his chief artificer, who came to beautify and adorn the temple, which, when completed, "every part thereof fitted with that exact nicety, that it had more the resemblance of the handiworkmanship of the Supreme Architect of the Universe than of human hands."

We cannot attempt here to catalogue, even, the great works that mark the migrations of those Hamitic builders to the east and to the west along both shores of the Mediterranean. But in a review of remarkably great works of the ante-classic age, it is proper to take note of the marks of skillful builders who in the distant past possessed portions of Mexico and Peru.

Ewbank, speaking of ruins of ancient hydraulic works in Mexico, Peru, and Chili, says: "Some of them rival in magnitude those of Egypt and India, and the roads equaled in utility the oldest works of Greece and Rome." The base of the great pyramid of Cholula, which is by some Mexican explorers attributed to the Toltecs, and who are by some ethnologists classed as Turanians, measures 1,440 feet, a little more than one-quarter of a mile on each side, and covers nearly four times the area of the largest Egyptian pyramid. The great pyramid of Palenque was carried to a height of sixty feet and then surmounted with a temple.

Humboldt says that few nations moved such great masses of building stone as those unknown people of Central America.

In the rainless lowlands of Peru hydraulic skill was as much a necessity as in the plains of Egypt and Chaldea. Says Humboldt: "In the maritime parts of Peru, I have seen the remains of walls along which water was conducted for a space of from 5,000 to 6,000 meters, from the foot of the Cordilleras to the coast." Examples are mentioned of water being conveyed sixty miles to irrigate a small territory, and Acosta describes an aqueduct of 120 leagues, or 360 miles in length, which at its fountain seemed to be a river, also another of 150 leagues in length from north to south, which traverses a whole province, and extends from the mountains to the plains.

Acosta, when examining the ancient buildings in Peru, was at a loss to comprehend how they could have been erected, so large, well cut, and so closely jointed were the stones.

In the prehistoric times there was another colony whose origin is still in dispute, though probably Turanian, that planted itself on the north shore of the Mediterranean, and excavated tombs, and built strongholds of Cyclopean masonry about the Archipelago. We call them Pelasgians. They built dams and canals of surprising magnitude and of skillful construction, and infused into their conquerors an influence without which the temple of Diana at Ephesus would have been impossible. We see traces of their works at Athens, at Eleusis and Isene, and at Samos, where there is a conduit tunnel originally counted one of the seven wonders of the world.

Also a colony whose origin is uncertain, but claimed to be Pelasgic, planted itself on the west coast of the Italian peninsula, and at the dawn of history was excavating temples in the rocks similar to the Egyptian models, and adorning their entrances with massive facades of columns and lintels and majestic sculptures. We call them Etrurians.

Their advance in civilization expressed itself in innumerable works of masonry of massive character, and in works of art. They drained and sewered their towns, reclaimed marshes, and embanked lowlands. So skillful were they in engineering works of magnitude and public benefit, and so skillful in surface decoration of their houses and wares, that the Latins, who afterward absorbed them, became their willing disciples in skillful building and in art.

It seems that in process of time those Turanian colonists that separated from the Egyptian homestead disappeared, or were absorbed by conquests, leaving only their constructive impressions in the lands they possessed for a time; but they made their marks as though for eternal mementoes of their presence.

The home colony survived, with occasional disaster, till within the historic period, and as the successive Egyptian dynasties flourished, then were wrought in Egypt such great national works and structures that beside them, so far as magnitude and massiveness are concerned, our modern works seem feeble in comparison, and so far as mechanical finish of decorations is concerned, Viardot informs us that their statues and bas-reliefs in granite, porphyry, diorite, and basalt have often a fine polish and exquisite delicacy suitable to cameos and precious stones.

Then the *mechanical* treatment of stone reached with the Turanians a perfection not since surpassed, but the highest æsthetic and scientific treatment of stone was waiting for other more intellectual and refining influences.

At the dawning of history we find in the upper peninsula of Greece and in adjacent portions of Asia Minor groups of inhabitants of undoubted Japhetic origin. They in time absorbed the Pelasgic builders, and began to build temples worthy of dedication to the gods and goddesses of their religious system, to gather towns about their temples, to establish republican systems of government, to build gymnasiums for physical development and to build forums for public discussions and mental development. They became, at the dawning of the classic age, the most prosperous and enlightened branch of the so-called Aryan race. As a result of their thrift Argos, Mycenæ, Athens, Sparta, Thebes, and Corinth grew to wealth, power, and renown; their merchants were princes and their scholars were giants in intellectual power. Intellectual strength was as marked a characteristic of their race as mechanical skill of the Turanians. Out of their mental resources came in due succession the poems of Homer, the laws of Lycurgus, the architecture of Ictimus, the sculptures of Phidias, and the bronzes of Polycletus, each unsurpassed to this day in intellectual excellence.

The cities of Greece welcomed the skilled artisans of Phœnicia, and the expert workmen of Etruria encouraged their Pelasgic masons, and became themselves most excellent builders. They superadded to mechanical excellence an artistic influence that gave to the art of building the intellectual refinement of form and proportion that found expression in such structures as the Doric temples of Juno at Argos, and of Jupiter Olympus; the Ionic temple of Apollo Panonius and the theater of Laodicea; the Corinthian monument of Lysicrates and Arch of Adrian, and in the Parthenon at Athens. By their hands the æsthetic treatment of stone, in temple, in monument, and in mythological sculpture, reached the utmost perfection yet attained.

The scientific treatment of stone was then advancing toward excellence among the dome builders of northern Italy, and afterward reached in the vaulted

arches of the southern cities a high degree of perfection, culminating in the domes of St. Peter's at Rome and St. Sophia at Byzantium.

At the time of the death of the Grecian Emperor Alexander the Great (323 B. C.), the Roman republic, embracing Latins and Etrurians, was already established and thriving, and in a brief time it gathered in by conquest the *Aryan* colonies of Greece, the *Turanian* colonies of Carthage and Egypt, and *Semitic* colonies of Syria and Assyria, and to the northward the *Celtic* colonies of Gaul and Britain, and boasted the rule of three thousand five hundred cities, so that a half century before our era she

> "Reigned absolute, the mistress of the world;
> The mighty vision that the prophets saw
> And trembled."

Rome had then at command all the elements out of which develop with spontaneous growth durable and magnificent building, for they possessed the *mechanical* skill of the Turanians, the *scientific* skill of the Celts, the *artistic* skill of the Aryans, and the *financial* skill of the Semites, and the wealth of all civilized cities paid her tribute.

It was during the three centuries of the expansion of the Roman empire that her most beautiful temples and theaters and her greatest aqueducts were built and the fountains and public baths of her capital assumed their most magnificent splendor, and her Roman architecture rivaled in elaboration that of Corinth and Athens. Tarquin the elder, who was of Etrurian birth and Pelasgic descent, projected the cloacæ for the purification and drainage of Rome, and his grandson, Tarquinius Superbus, completed the *cloaca maxima*, famous for its size and the stability of its arch masonry, which, though 2,300 years in use, has ever been a wonder to visitors because of its magnitude and excellent workmanship.

Frontinius, an officer of renown, appointed by Nero to the charge of the aqueducts of Rome, gives the total length of the nine great aqueducts as 277 miles, 31 miles of which were on arcades. On the plains near Rome may be seen the most of these splendid masonry arcades, partly in ruins, nevertheless monuments of the mechanical skill and artistic treatment of two thousand years ago. Within the city of Rome the masonry of some of the aqueducts was embellished with elaborate architectural ornament, as for instance Aqua Virginie, which has a facade of the complete Corinthian order with columns and entablature in full relief. At some of the main thoroughfares which the aqueducts span, the arcades equal in grandeur and nobleness of design triumphal arches, and bear inscriptions; and certain *castella* exhibit choice examples of classic architecture and sculpture.

If we had time now to examine the most important of the colonial work of the Romans previous to the decline of the empire, we should find it to include some of their boldest works, and we should find their most skillful works to be aqueducts and amphitheaters.

For instance, one of the great aqueduct bridges of the Pisan aqueduct, with its thousand arches, is still famous, and the *Pont du Gard* projected by Agrippa at Nismes is famous, and the aqueduct supplying Lyons has one arcade of three stories of arches, another of five stories of arches, and still another of eight stories of arches, with a total height of nearly three hundred feet; and, for instance, also the great amphitheaters at Capua, at Nismes, and at Verona, as remarkable in magnitude and decoration for colonial works as the great Colosseum at Rome for a splendid metropolitan structure.

These brief references to the splendid and durable workmanship of the ancients must not be considered exhaustive of the range of their works even.

We might also trace the growth in their mechanical skill in harbor works, in the moles and piers and fortified entrances of the Phœnician, Greek, and Roman ports, that grew out of their commercial necessities, also in their great walls, towers, and massive gates that grew out of their military necessities, or in their bridges, which in the hands of the early Romans displayed such thorough knowledge of the regimes of rivers, and of foundations, and of counter-arching that they became practical models for the more theoretical engineering of France and Britain many centuries later.

The gathering in of the best talent of the subject races to the powerful Roman capital and Roman cities bore good fruits in the production of very many well considered buildings of the most thorough workmanship and elaborate details and admirable models of usefulness. Their masonry, proportions, and decorations have exerted a strong influence in subsequent buildings in the classic revivals.

The dominant race had not, however, the fine feeling that enabled them to appreciate and generally embody in their works the chaste beauty of the Ionic builders, so that while mechanical building advanced in usefulness, art, in its highest application to domestic and municipal structures, began to recede, even while the glory of the Roman empire was in ascendency.

In time the glory of the Roman empire culminated, and the period of ancient skill and art rapidly declined. About three and one-half centuries after the beginning of the Christian era (364 A. D.) the dismemberment of the Roman empire began. The exultation of conquest was no longer an incentive to great public undertakings. On the contrary, there was a decrease of national energy and a decrease of national revenues. The desire for durable structures and artistic embellishments gradually weakened, and there was no longer a pressing demand for skilled workmen and skillful artists.

From this period, fifteen hundred years ago, the historical study of ancient mechanical skill and more especially of ancient fine art leads into a quiet gloom, for the arts then began a slumber of five centuries' duration in nearly all Europe, through the long night of the "dark ages."

The examples of wondrous skill among the ancient mechanics, though now much scored by the storms of twenty to thirty centuries, are still so numerous that this brief sketch but suggests a research among them.

Omitting now a consideration of mediæval skill and art, we pass from the assembled Turanians, Aryans, Semites and Celts, under Roman conquest, to a present period when, after twenty centuries' interval, imperial liberty and prosperity are gathering anew on American soil the stock and traits of Semite, Aryan, and Celts, with their financial, artistic, and scientific instincts, and out of which, under a fair financial stimulus, ought to grow public structures of wondrous skill and beauty; but the spirit of the Turanian, the mighty builder, has not here an influential representative.

We are proud of the mastery of the forces of nature, our mechanical inventions, our splendid trusses, and our technical refinements of structures have not been surpassed in former eras. We are proud of an industrial progress that gives us almost unlimited constructive possibilities, but yet there remains to be developed an admiration and an introduction of enduring qualities in our structures.

If there is aught that is admirable in the public will of our generation that should awaken a spirit of reverence in later generations, then the standard of the public structures should respond to a natural demand, and out of the high scientific attainments, the constructive genius, and the artistic refinement of which we boast should be evolved structures that will be admired at least a century hence with admiration equal to that we give to the unquestioned skill and art of the heathen of forty centuries ago.—*Jour. Association of Engineering Societies.*

THE COMPOUND PRINCIPLE AS APPLIED TO LOCOMOTIVES.*

By EDGAR WORTHINGTON, C.E.

THE author stated that the primary object of the various attempts which had been made during the last thirty-six years, and more especially within the last ten years, to apply the compound system to locomotive engines was to expand the steam in the cylinder more than was commonly done at present, and thus to save fuel. In an ordinary engine, during the first portion of the forward stroke of the piston, the steam, at say 180 lb. pressure and a temperature of 379·7° Fah., was suddenly admitted to a cylinder at 253·9°, and instantly began to condense and lose its pressure. During the latter half of the forward stroke the water of condensation was re-evaporated into steam, which action continued during the return or exhaust stroke, extracting heat from the warm cylinder. If, on the other hand, steam at 180 lb. was expanded through two cylinders on the compound system, with a receiver pressure of 80 lb., the average temperature of the high-pressure cylinder would be 98° above that of the low-pressure cylinder.

Condensation and re-evaporation would still go on in each of these cylinders; but the steam at 180 lb. pressure would, in one case, enter a warm high-pressure cylinder at 338°, and in the other a cool single cylinder at 253·9°, there being a difference of 84·1° in the temperatures of the two cylinders in favor of the high-pressure one. The chilling action of the exhaust steam at 212° would no longer be felt in this small cylinder, so that work would be developed in it before much steam could be condensed. The final exhaust steam could only draw heat from the low-pressure cylinder, the temperature of which would be 240°; whereas, in the ordinary engine before named, the single cylinder was maintained at the higher temperature, 253·9°, thus having more available heat to be extracted and wasted by its exhaust steam.

It would also be noticed that the whole of the heat absorbed from the high-pressure cylinder by re-evaporation, during the latter half of the forward stroke, and the whole of the return stroke of the high-pressure piston, would be utilized in maintaining the pressure in the low-pressure cylinder. From this point of view, therefore, less heat would be thrown away by re-evaporation in engines built on the compound system than in ordinary engines. The same reasoning might be applied to triple and quadruple expansion engines. But the extremes of very early cut-off and multiple expansion, in triple or quadruple cylinder engines were beyond the scope of practical locomotive engineering, where the limits of working had hitherto been found to lie within an eightfold expansion and two cylinders.

After giving a historical account of the application of the compound system to locomotives, from the date of Mr. James Samuel's "continuous-expansion engines," in use on the Eastern Counties Railway in 1852, to the modern compound engines now being adopted in all parts of Europe, and specially noticing the share of Mr. Anatole Mallet in the general introduction of the system, the author proceeded to consider the proper capacity of the low-pressure cylinder in relation to the high-pressure one. Mr. Mallet, who had experimented, perhaps more than any one else, on this question, stated in 1883 his conclusions that the low-pressure cylinder should have a volume at least double that of the high-pressure cylinder, which was confirmed by Mr. Von Borries and Mr. Worsdell's practice. Mr. Webb adopted the larger cylinder ratio of 2·25 or 2·30 to 1, without inconveniently crowding the cylinders, and was thus enabled to obtain a higher ratio of expansion for the steam.

Mr. Mallet had always preferred to make the point of steam cut-off in each cylinder variable, and he therefore employed two independent reversing gears. Mr. Webb's ingenious single screw reversing gear allowed the steam cut-off in both high and low-pressure engines to be adjusted independently. Mr. Borodin fixed the cut-off in the low-pressure cylinder at from 70 to 73 per cent., and varied the speed of the engine by adjusting the high-pressure cut-off, and by the regulator. Mr. Von Borries made the lifting links of different lengths, the difference being about $\frac{1}{7}$ the total lift of expansion link. This gave a later cut-off in the low-pressure cylinder.

All locomotives should be able to exert at starting their full tractive power. In the Worsdell and the Von Borries types of compound locomotives a special starting valve was provided, enabling the engine to exert more power during its first revolutions than afterward when in motion. There were certain positions in the three-cylinder compound engine when the high-pressure axle only was available for starting; but as a superabundance of power was brought to bear upon this one axle, owing to the absence of back pressure in the receiver, the use of sand beneath the tread of the wheels might enable the engine to start at all times with a very heavy load. The high-pressure cylinder should be made about 1 in. larger in diameter than the cylinders of an ordinary engine of equal power, even though an advance of 30 lb. per square inch of boiler pressure was contemplated for the compound engine. At very great speeds, where high expansive working was essential, compound engines used the steam more efficiently than simple engines, and under these circumstances appear to greater advantage than at low speeds. Indicator diagrams had been taken from Mr. Webb's engine, showing over 1,000 horse power, and Mr. Worsdell's passenger engine, with its ordinary average train, indicated 911 horse power at sixty miles per hour. A most detrimental steam wire-drawing took place at the edge of the slide valve itself; and as the low-pressure valves in compound locomotives must necessarily be very short compared with the diameter of their cylinders, the Allen, or double ported, valve had been used, to double the effective length of the steam admission port. In ordinary cases, the steam ports of slow moving goods engines need not be so large as those of passenger engines running at high speed.

The receiver capacity of a two-cylinder compound locomotive, having its cranks at right angles to each other, should be not less than the capacity of the small cylinder; for it must be capable of containing at least one-half the small cylinder full of steam, discharging during the latter part of the stroke of the low-pressure cylinder, when the latter was not taking steam, as well as the steam which was left in the receiver after the previous stroke. The largest amount of work would be obtained from the expanding steam in a compound engine if the cut-off in the low-pressure cylinder were permanently fixed at a point where the volume of steam admitted wouldbe equal to the capacity of the high-pressure cylinder. This advantage, however, must be sacrificed; for it was more important to arrange the low-pressure cut-off so as to divide the work equally between the two cylinders.

The use of high pressures in one cylinder, with a single slide valve controlled by any ordinary valve gear, was attended at high speeds by much loss of pressure, caused by throttling and condensation of steam. Therefore, pressures of 150 lb. to 200 lb. were worked most economically either by independent steam and exhaust valves, as in the Corliss engine, by double slide valves, employed on the Central Pacific Railroad since 1883, or, if ordinary locomotive valve gears were used, the steam must be expanded through more than one cylinder; that was to say, the locomotive must be compounded. An average saving of 18·8 per cent. was effected in fuel by the substitution of compound for ordinary engines, the boiler pressure being higher in the compound engine than in the ordinary engine.

The following minor advantages might be classed under this head: (1) Prolonged expansion of steam in one cylinder was avoided; the high-pressure steam developed the first portion of its work in a very hot cylinder, and the latter portion in a cooler cylinder; (2) re-evaporation was not so great as in an ordinary engine; condensation took place chiefly in the cool, low-pressure cylinder, and very little heat was abstracted by re-evaporation from the high-pressure cylinder; (3) leakage at the pistons was reduced, the effective pressure per square inch on each piston being small; (4) high grades of expansion could be frequently used, without the withdrawing action attending an early steam cut-off; (5) the wear and tear of the boiler was less, notwithstanding the higher pressure; (6) the force of the blast was lessened, and fewer sparks were drawn through the tubes and thrown from the chimney. The boiler was required to evaporate only from 80 to 85 per cent. of the water necessary for an ordinary engine to do the same work; and thus, of two boilers of equal size, the one on a compound engine was not driven so hard, and would, therefore, last longer than the other on a non-compound engine.

Compounding, on the other hand, compelled a certain amount of expansion, and on the other allowed more than double the expansion possible in the ordinary engine. The blast pipe could be made $\frac{1}{4}$ in. or $\frac{5}{8}$ in larger in diameter, and the beats of exhaust being lighter and reduced to half their previous number, the tearing action of the blast was diminished, especially at high speeds. The pressure on the piston, and consequently the working strains throughout the machinery, were more uniform when steam was expanded through two cylinders than when the same ratio of expansion took place in one cylinder. In simple engines working with high expansion, the pressure on the piston at the beginning of the stroke was greater than in the compound engine. This was the portion of the stroke when the progress of the piston was small, and the crank was doing the least amount of useful work; therefore, in a simple engine, the increased pressure at the beginning of the stroke, while creating a corresponding increase of friction on the crank pin, caused very little extra useful effort. Again, the sustained pressure during the stroke of the compound engine was advantageous, because, in the middle of the stroke, nearly all the pressure was transformed to useful effort, and a relatively small proportion was lost in friction.

When at work, the effective pressure per square inch on the back of compound engine valves was less than that on the valves of ordinary engines, inasmuch as the sum of the pressures on the high-pressure and low-pressure valves could not together exceed the boiler pressure. But the full boiler pressure, and consequently heavier strains, were brought to bear upon the high-pressure valve and machinery, both when the locomotive was starting and at other times, when the high-pressure and low-pressure engines were worked independently with live steam, admitted to the cylinders by means of the various automatic and non-automatic starting valves in use for that purpose. The more uniform distribution of strains enabled compound locomotives to run with exceptional steadiness.

This result, however, might be partly due, in the German and in the three-cylinder compound engines, to the position of the cylinders, which were placed far back near the middle of the wheel base, where their disturbing influence was little felt, and also to the position of the large central low-pressure cylinder, the disturbing forces of which, though great, lay on the center line of the locomotive. The increased power of starting a train belonged only to those compound engines fitted with one of the numerous intercepting or starting valves. The effect of these valves was to admit steam to both cylinders direct from the boiler, and at the same time to prevent this steam so admitted to

* A paper recently read before the Institution of Civil Engineers.

the large cylinder from acting as back pressure on the small piston. It was evident that a large increase of tractive power might thus be exerted at starting, which was useful in overcoming the friction of rest of a long train.

The adoption of high-pressure steam was attended by the following drawbacks: The boiler and all steam joints must be more carefully made. Only the better kinds of lubricants were admissible, such as were not decomposed at the higher temperatures of this steam. The gland packings must be constructed to withstand heat, for which purpose several systems of metallic packing had given good results. For using very high-pressure steam in compound engines, it had been suggested that the first cylinder, which would be small, should be made of gun metal or steel, because high-pressure steam corroded cast iron. Until suitable piston valves had been invented for the high speeds required by locomotives, these increased steam pressures might be dealt with by balancing the ordinary side valves—a practice successfully carried out in American locomotives for the last eight years, and which was being revived in this country by Mr. Webb.

Large cylinders were an essential feature of the compound system. They were cumbersome and had more cooling surface than small, compact cylinders. Much valuable heat might be lost if the large cylinders were not carefully protected by wood, felt, or air jackets. A large quantity of water of condensation might be observed in the chimney, thrown from the blast pipe of the large low-pressure cylinder. At each end of this cylinder Mr. Webb and Mr. Worsdell placed safety valves, which relieved it of any undue pressure caused by the accumulation of water. This large cylinder might also be drained by cutting a groove in the low-pressure cylinder cocks, about $\frac{1}{10}$ in. wide, to allow a constant leak of the condensed water. The momentum of a piston, 26 in. or 30 in. in diameter, together with that of the other reciprocating parts of the large engine, caused severe strains, which must be provided for.

Those compound engines which had more than two cylinders, connecting rods, and valve gear had a corresponding additional number of joints and wearing parts, and therefore required more oil than ordinary engines. In the two-cylinder compound system, it had been shown that the pressure on the moving parts was not so great or fluctuating as on the corresponding parts of a simple engine; and it might therefore be expected that the compound engine would need less lubrication than the simple one. This however did not appear to have been confirmed in practice. Whether it was due to the use in the compound engines of higher steam pressures, or to the extra oiling given to a new and less understood class of machinery, it was difficult to say; but several instances had come under the author's notice in which two-cylinder compound locomotives had required more oil than simple engines doing similar work.

There was a danger in "over-cylindering" a compound engine; for, when running with a light load, such an engine might be obliged to expand its steam to below atmospheric pressure. On the other hand, with a 4 ft. 8½ in. gauge, the difficulty of placing the two cylinders between the frames limited the power of inside two-cylinder compound engines. It followed, therefore, that the same compound locomotive could not adapt itself so well as an ordinary engine to both light and heavy traffic. It thus appeared that on long, level roads, and with such regular loads as were found on the Continent and in North and South America, the compound system might prove more successful than in Great Britain, where inclines were more frequent, traffic more varied, and fuel cheap. The system had hitherto met with most favor and success in Germany and in England. To save unnecessary expense, Mr. Mallet constructed his early compound locomotives as much like the ordinary locomotives as possible. There could be little doubt, however, that a compound engine, as constructed now, was a little more expensive in first cost than a simple engine of the same maximum power.

In the compound engine, the boiler, steam pipes, joints, etc., must be made stronger, to resist the greater pressure, and extra precautions had to be taken to prevent radiation from the hotter boiler, the high-pressure cylinder, and from the increased surface of steam pipes where they were exposed. These extra items were to some extent balanced by the smaller size of boiler. To roughly estimate the justification for adopting the compound system, it might be interesting to compare the cost of fuel consumption by a compound locomotive with that of a simple engine, running during one year 20,000 miles, and burning 30 lb. of coal per mile, which figures were slightly below the average for English railways. Coal burnt in one year by an ordinary locomotive

$$= \frac{20{,}000 \times 30}{2{,}240} = 268 \text{ tons.}$$

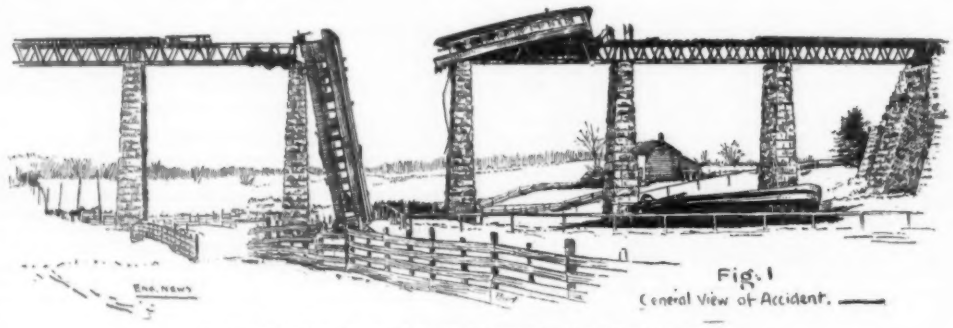
Coal saved by compound, 15 per cent. of 268 tons=40 tons. Thus, in a country where coal cost 10s. per ton, £20 per annum would be saved. This represented interest at 5 per cent. on a capital of £400; and if the cost of maintenance were the same in the two engines, and the lifetime of each were, say, twenty to thirty years, it might be concluded that, in a country where coal cost 10s. per ton, an extra outlay, not exceeding £400, would be justified in the price paid for the compound engine. Under the above conditions, a two-cylinder compound would be very economical; but the saving of the more expensive three-cylinder compound would be about half swallowed up by the additional interest on its first cost; and it was not likely that the four-cylinder compound would be economical. The cost of converting ordinary engines into compound engines was greater than their difference of cost when both were new. A careful investigation into the cost of converting some small simple locomotives, on one of the Staffordshire tramways, to the compound system, showed that the value of the fuel thereby saved would not pay for the alteration in ten years.

It was probably due to the enterprise of English and German locomotive engineers that the compound system had hitherto been introduced so successfully where coal was cheap. Its success under these conditions was the strongest argument in favor of introducing the system into foreign countries which imported coal from abroad, as, for instance, Northern India, where the price of Welsh coal was £2 14s. 6d. per ton.

In conclusion, it appeared that the compound principle, in its application to locomotives, had been attended by considerable saving of fuel, but that sufficient time had scarcely elapsed to prove the value of some of the other advantages claimed. Increasing the number of cylinders to three or four rendered it possible to construct extremely powerful locomotives. Certain minor difficulties connected with the distribution of steam at low pressure had not yet been entirely overcome in compound locomotives running at high speeds; but although the system might not be suitable for engines working intermittent slow heavy traffic, yet on main line trains, and in countries where fuel was dear, its advantages were well established.

THE ST. GEORGE BRIDGE DISASTER.

ST. GEORGE is a small village of about 600 people on the Grand Trunk Railway, 21 miles west of Hamilton, Ont. The accident happened on the evening of February 27, to the so-called St. Louis express. About 1,220 feet beyond the bridge there was a switch, and



ST. GEORGE BRIDGE DISASTER—GENERAL VIEW.

352 feet from the bridge another switch, both on a ½° curve. Possibly something was wrong at these switches, but probably not. In any case, about 450 feet from the end of the bridge the engineer noticed that a driver tire was broken; it was so badly broken that it left the wheel, and rolled off into the field, about 150 feet from the end of the bridge, in sight of a passenger on the train. Then the coupling rod broke, very naturally, and it had been tearing up the roadbed for some distance before reaching the bridge, so that on entering the bridge the whole train was derailed; but it is evident from what followed that it was not then very badly derailed.

The bridge itself, so far as we can ascertain, consisted of eight spans of 50 feet each. The broken span is the fifth. The first two spans are not shown in our engraving. The structure itself we judge to have been in all respects a solid and substantial one, but the floor consisted only of what the superintendent calls "needle beams," on which the rails directly rested. We judge the sticks to have been about 8 × 12, and placed at least 8 inches apart in the clear, if not more. There was a heavy guard rail along the outer ends of these "needle beams," but there were no guard rails proper, close to the rails, and no rerailing guards at the end of the bridge. The roadmaster testified that the management did not believe in or use any such precautions, "even at Niagara."

To the ease with which this floor was disturbed and destroyed, rather than to the broken tire or coupling rod, appears to be due the disastrous consequences, which, according to the latest reports, have caused 13 deaths and 29 injuries, many of them serious, and a money loss of over $200,000. In the first place, it is highly probable that had the bridge been protected by rerailing guards, the derailed cars, at least, if not the engine, would have been restored to the rails as they passed on the bridge, and the final catastrophe postponed for 150 feet further, when the bridge would have been passed. Had the brakes been put on promptly, likewise (which does not appear to have been the case), the final smash-up might have been averted altogether.

But passing these possibilities, what immediately began to happen when the derailed train struck the bridge was that the "needle beams" were at once displaced and "bunched," leaving fearful gaps for the following wheels to bump over. The shocks produced by such blows, and by the broken coupling rod, might conceivably have destroyed the bridge by causing excessive strains, especially in such a light structure, but that the bridge was not destroyed in this way is evident from the fact that the engine, tender, baggage car, and smoking car passed entirely across in safety.

The passenger car also (the one furthest to the right on the ground) must have passed the span which finally gave way, in safety, as otherwise it would have struck the ground sooner. Its sad fate must have come merely from its derailment and not from the bridge failure. The broken span undoubtedly gave way under the rear truck of the parlor car, the front half (or two-thirds) of which is seen in both views, still perched on the structure. The heavy weight of the following dining car broke off the rear end of the parlor car, and the work of doing this so checked its own speed that it fell straight on end in the singular position shown, dropping its rear truck behind it through the demolished floor of the next span behind, where it will be seen caught in the ironwork.

The train consisted in order of the following vehicles, to which we append the fate of each.

1. *Engine.* 2. *Tender.* 3. *Baggage.* 4. *Smoking Car.*

Escaped, but were derailed, and disturbed the floor, pushing the ties ahead and gathering them together, causing wreck of the following coaches from track being unsupported.

5. *First-class Coach.*

First car to fall. Probably pushed off sidewise by the pressure from behind. Struck wheels down and at once collapsed. Every person in it killed or injured.

6. *Parlor Car, Toronto.*

Central truss apparently gave way under this, causing it to break in two, the larger half remaining on the bridge and the lower half falling. Several in the car escaped.

7. *Dining Car.*

Energy of motion destroyed, apparently in breaking off the rear end of parlor car ahead, so as to fall on end in the position shown. Every person in it killed or injured.

The position of the wreck is, to our mind, proof positive (1) that none of the cars had wandered far from the track, and (2) that if the "needle beams" had not been so widely spaced and so little bound together by guard rails and otherwise as to be readily "bunched," nothing serious would have happened. The fate of the first-class coach may seem to indicate the contrary; but in all probability, as noted, this car first broke loose from the cars in front, and then was pushed by its own inertia and by the cars behind along the edge of some slanting needle beam, or was diverted in the direction of least resistance for a twisted truck.

The coroner's jury distinguished itself, as usual, by the following lucid and intelligent verdict:

"We also exonerate the railway company and their employes from any blame in the matter; but would respectfully recommend that the company cause all fast trains to slacken their speed when approaching the St. George station, especially eastbound trains."

ST. GEORGE BRIDGE DISASTER—SHOWING CONDITION OF BRIDGE FLOOR.

To slacken speed to 12 miles per hour (as was recommended) on so small a structure forever after, because of one accident, is a quite senseless precaution: but we could not, if on a jury, exonerate from blame for what has happened the management of that or any other corporation which had spaced ties so far apart and neglected to provide any effective guard rail system. The probabilities are exceedingly strong that had the "needle beams" been spaced two inches apart, instead of eight inches, not a life would have been lost, nor a car nor span wrecked. To have done this, calling the bridge 400 feet long, would have required the immense aggregate of something like 17·28 M feet B. M. more timber, which at $30 per M might mount up to the heavy aggregate of $518.40. To save this paltry sum, half a hundred lives have been placed in imminent danger and 13 lost; millions who have passed over the bridge have been in possible danger; and $200,000 in money has now been lost, enough to give a proper floor in this detail to 400 such bridges. In view of this, it is certainly not too much to say that such loose-jointed floors are quite as much a crime as a blunder, and quite as much a blunder as a crime. Yet in spite of such reiterated warnings, men will keep repeating them.—*Engineering News.*

EXHIBITION OF CYCLES.

THE annual exhibition has been held for the first time at the Crystal Palace, Sydenham, London. Even the magnificent central transept of the Palace failed to provide the space required, and some of the courts had to be occupied. It is estimated that 1,200 machines were exhibited, the major portion of which were of the rear-driving safety type.

The exhibition this year shows a definite settling down to existing patterns rather than the introduction of any new types, and certainly no previous exhibition has been so devoid of monstrosities and fads, which serve no other purpose than to show to what waste an inventive mind can be turned.

Taking the exhibits in their natural classification, the ordinary bicycle remains as of old, little attention apparently being devoted to this type of machine, no doubt owing to the state of perfection to which it has been brought. The slight alterations indicate the use of a larger trailing wheel, greater rake to the front fork, and increased length of crank, all evidently introduced to give this type of machine the comfort and safety of the rear-driving bicycle.

Turning next to the rear-driving safety bicycle, which from the number exhibited is evidently at the present time the most popular type of machine, no startling novelties are shown, but a greater degree of excellence in design and construction is conspicuous throughout the exhibits. Makers are at last grasping the advantage to be derived from staying the frames, and few machines with the cross frame are exhibited without any stays. The most popular type of frame appears to be the diamond-shaped, a specimen of which is shown by Fig. 1. This machine is the latest introduction of the well-known firm of Humber & Co. The frame consists of double members throughout, with the exception of that running from the seat pillar to the steering post. This frame is trussed between the top and bottom members, but many machines with diamond-shaped frames are exhibited without this truss, and it seems open to question whether a frame such as we illustrate is not too rigid, thereby throwing an increased amount of vibration on the joints and connections. A novel construction of frame is shown by Fig. 2, which illustrates a machine shown for the first time by a new firm, Messrs. S. P. Thomson & Co. This frame is of the cross type, each member being formed of two tubes, the extremities of which are well stayed to one another by light rods. This makes an exceedingly light and rigid frame.

Messrs. W. Andrew show a machine which, if it is capable of doing what is claimed for it, must entirely revolutionize this type of machine. It is claimed for this machine that it can be ridden as easily without the use of the hands as the ordinary bicycle, and that any one who has ridden a bicycle of the ordinary type, but not one of the rear-driving type, can mount this machine and ride straight away. To fully grasp this it must be understood that the safety bicycle is far more difficult to ride than the one of the ordinary type. This is self-steering is brought about by mounting the saddle on an arm or lever pivoted at about the center of its length to the main frame of the machine. The free and forward end of this arm or lever engages with a lever extending rearward from the steering post; consequently the saddle is caused to move with the steering wheel, and comes to the same side as the steering wheel turns. Thus the action of inclining the body to one side through the feet on the pedals causes the saddle to come over to that side, and operates the steering wheel accordingly.

As the pin on which the arm or lever carrying the saddle is pivoted is raked back at the same angle as the steering post, the saddle rises slightly as it moves out of center with the machine; consequently the action of gravity tends to keep the machine running in a straight line.

Messrs. Jelley Brothers also show a self-steering safety bicycle, but the principle on which it is constructed is entirely different from that of Messrs. Andrews. In this machine the self-steering action is obtained by mounting the steering head or joint in advance of the steering post, so as to give the steering wheel a caster action. We understood this has been extensively tested during the past season, and has proved so successful in practice that Messrs. Humber & Co. have obtained the sole license to manufacture under the patent, and will shortly place the machine on the market on a large scale. Messrs. Jelley Bros.' safety bicycle is also fitted with a singularly neat contrivance for mounting the driving wheel, whereby it can readily be removed from the fork or frame carrying it without disturbing the bearings or springing the frame. This allows the gear of the machine, or even the driving wheel itself, to be altered with a minimum of trouble.

When we predicted last year a future for the tandem safety bicycle, we did not anticipate that in the short space of one year this type of machine would become so popular. Whereas only five makers exhibited machines of this type at the exhibition held twelve months ago, over a score of manufacturers exhibited these machines at the Crystal Palace; out of this number eighteen are of the "Lightning" type which we illustrated last year. The owners of the patents for this type of machine—the Lightning Tandem Bicycle Company—have, we understand, ceased to manufacture machines, but are granting licenses to the trade to do so, and with but few exceptions the exhibitors of this type of machine hold licenses from this company. The machine illustrated by Fig. 3 is one manufactured by Mr. F. W. Hall, the inventor of this type of machine, and the frame is so constructed that the center part can be detached and the machine converted into a single bicycle, by connecting together the two extreme parts of the frame.

In tricycles the most striking innovations are those for the use of two or more persons. The Rudge Cycle Company exhibited a machine for three riders, on which one mile has been ridden on the high road in the wonderful time of 2 minutes 18½ seconds. The machine has a pair of driving wheels on a balance-geared

Fig. 1

Fig. 4

Fig. 2

Fig. 3

Fig. 8

Fig. 9.

EXHIBITION OF IMPROVED CYCLES.

axle, and a pair of steering wheels immediately in front of the driving wheel, and each turning on independent centers by means of a differential steering gear, which turns the steering wheel nearest to the center of the path of motion through a greater angle than the outside wheel; thus great stability is obtained. All the driving power is communicated to the one pair of driving wheels. The same firm introduce a single tricycle constructed on the same lines, for which they claim great stability and safety, setting off the advantage of two tracks against the extra weight of the fourth wheel. We illustrate this machine by Fig. 4.

FIG. 5.

Messrs. J. K. Starley & Co. and the Nottingham Cycle Company each exhibited a novel machine for two riders, built very much on the same lines. We illustrate the machine manufactured by the latter firm by Fig. 5. The riders are seated directly over the driving wheels, so that the width of the machine is little more, if any, than an ordinary tricycle. The machine we illustrate is adapted to convert into a machine for a single rider by bringing one of the saddles and the steering handle bar into the center of the machine, as this type of machine cannot be ridden by a single rider seated over one of the driving wheels. The driving wheels are mounted on a balance geared axle, on to which both riders drive from the pedal crank axles. A modified form of this type of machine, obtained by

FIG. 6.

coupling two rear-driving safety bicycles together by stay rods, was shown by the Cycle Improvements Syndicate and Messrs. Ashton, James & Co. While the latter firm offer their machine as a practical sociable for two riders, the former only adopt this method of coupling two machines together as a means for one rider to propel both machines in case of emergency, and particularly for military purposes. In this we think they are right, as we believe the machine exhibited by Messrs. Ashton, James & Co. is quite impracticable for ordinary riding, inasmuch as the steering by means of the coupled steering posts, without any differential arrangement, will render the machine very unstable at anything like a high rate of speed. As a simple expedient for enabling one rider to move forward with two

FIG. 7.

machines, we believe the simple device of the Cycle Improvement Syndicate will be found exceedingly valuable for military purposes, as experience has shown that it is exceedingly difficult for one person to even walk and push two of these machines over any length of ground.

Of the cycles adapted for military purposes, fewer are shown than at the last exhibition, doubtless owing to the small demand; for although the past year has conclusively shown, both by the trials in the regular army at Aldershot and more particularly in the volunteer force, that the cycle can be most effectively used as a means of rapid transport, the introduction of any improvements in the British army is so surrounded by red tapeism that time must elapse before any considerable demand will arise for cycles for purely military purposes. Of the machines shown, only those by the Cycle Improvement Syndicate show that perfection of detail which arises from practical experience. In these machines, which are the invention of Sergt. Watkins, of the 26th Middlesex Cyclists Corps, no detail has been overlooked. The rifle is carried in a neat leather sheath, by which it is well protected from dust and dirt, and is supported in the most convenient position on the machine. Means are also provided for carrying ammunition, signaling lamp and flag, and valise, while in the safety bicycles an exceedingly simple device is provided for keeping the machine in an upright position when at a state of rest, so that the rider can remain mounted at the halt, and start and stop without dismounting. We are particularly struck with this device, and if the safety bicycle is to become a popular type of machine for ladies, of which there are some signs by the number of ladies' bicycles exhibited, we think this standing gear will be found a *sine qua non*.

With the introduction of the rear-driving safety bicycle has arisen a demand for anti-vibration devices, as the small wheels of these machines are conducive to considerable vibration, even on the best of roads. Nearly every exhibitor of this type of machine has some appliance to suppress vibration. Of those exhibited for the first time too many are conspicuous by their complication; we should imagine that their designers were in many cases ignorant of the first principles of mechanics. The Midland Cycle Company exhibited both a bicycle and a tricycle, which we illustrate by Figs. 6 and 7, fitted with a spring fork of novel construction. The steering wheel is mounted in a supplemental fork pivoted at about the center of its length to, and in front of, the main fork. Between the two forks springs are interposed, so that the fork carrying the wheel has not only a slight vertical movement, but also an approximately horizontal one, thereby allowing the wheel to give way slightly when striking an obstacle on the road. The main frame of the bicycle is formed in two parts, hinged together at the pedal crank axle, the movement of the hinge being controlled by a spring connecting a forward extension of the rear part of the frame with the forward part thereof. The main frame of the tricycle is also fitted with a spring device. That part of the frame carrying the saddle is pivoted near to the pedal crank axle to the other part of the frame, and is supported by a coiled spring.

This, with the spring fork in front, gives an easy movement, without varying the relative positions of the cranks, handles, and seat. The Bradford Cycle Company, the latest of limited liability companies in the cycle trade, showed machines fitted with Redman's spring fork—see Fig. 8. In this case also the steering wheel is mounted in a supplemental fork, which is adapted to slide within the main fork, its movement being controlled by a spring concealed in the tubular steering post. Mr. Weston exhibits several machines fitted with his spring frame, which is greatly improved since its first introduction at the last exhibition. In this machine, which we illustrate by Fig. 9, the saddle and pedal crank action are mounted on a frame, which is suspended from the main frame by links supported by a strong coiled spring. This is most effectual in isolating the rider from vibration, but it has the objection that the position of the rider with respect to the handles is always varying. The spring fork carrying the steering wheel will be self-explanatory.

One of the greatest novelties in spring forks is that shown by Mr. Bown, the well-known maker of the "Æolus" ball bearings. It is, we believe, an American invention, and consists of a C shaped spring on each side of the wheel, connected at the top to the root of the steering post, and at the bottom to the axle of the wheel. Each spring consists of two steel wire rods, and the whole are braced together to form a transversely rigid yet vertically elastic fork. Following the example of our traction engine makers, the Quadrant Cycle Co. exhibited a spring wheel, but we do not fancy this invention has any future before it, as we foresee many practical objections to such a device. The Oarsman tricycle, which we illustrate by Fig. 10, is shown in an immensely improved form, and we think that the inventor, the Rev. M. Taylor, should now be within measurable distance of realizing something by his invention, at which he has labored so long and perseveringly. We have always been struck by the powerful action of this machine, and we believe that the sole reason why it has not become popular is from an erroneous impression that it is a hand power machine, while such is not the case. It is practically a combined leg and a hand power machine, the leg power being obtained by means of the swinging seat in the most direct and powerful manner, viz., by thrusting back from a fixed foot board with the small of the back by means of a back rest on the swinging seat. The arm power is only exerted by means of the hand levers toward the end of the stroke as a quickening and supplemental action to the leg power. We understand that a syndicate is being formed to place this machine on the market, and we have little doubt that when it finds a place there, a demand will soon arise for it, solely from its intrinsic merit.

Among the number of accessory parts we notice an oil-tight gear cover, introduced by Mr. Harrison Carter, the well known milling engineer. This gentleman is so convinced from practical experience in milling machinery that there must be a great loss of power in chain-driven machines, not only from the want of efficient lubrication, but also from the dust and dirt that accumulate on the chain and chain wheels, that he is endeavoring to educate the manufacturers and riders generally up to the advantage to be derived from inclosing the chain gear and efficiently lubricating it. There can be no two opinions as to the advantage to be

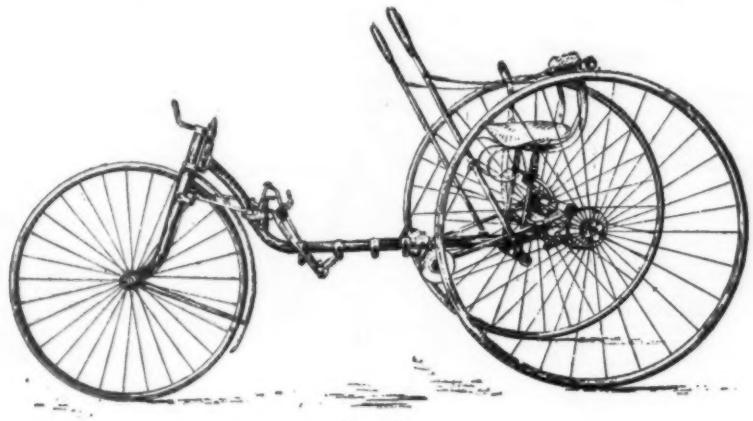


FIG. 10.

derived, and it only remains to be seen whether a gear case can be fixed to cycles in a satisfactory manner. We think that it can; but we do not disguise the fact that it is no simple matter, owing to the enormous vibration and variety of strains to which the frames of these machines are subjected.

So satisfied are we that Mr. Carter's theory is right, that we are having his gear case fitted to a machine for practical trial. Space will not permit us to notice many interesting novelties in the various fittings of cycles, but we express our warm approval of the bifurcated saddle of Captain Pattison, which, from the medical testimonials that have been bestowed upon it, seems to entirely obviate that pressure, which the medical faculty tell us is the only evil that arises from cycle riding. Messrs. Bagshawe Brothers, of Sheffield, exhibited samples of steel castings produced by a new process, which they claim to be superior to anything yet produced. Taking the samples exhibited as fair specimens, we do not think they claim for their patent steel castings more than they are fully entitled to. From the number of cycle manufacturers who are using these castings, it is only fair to assume that they give satisfaction.

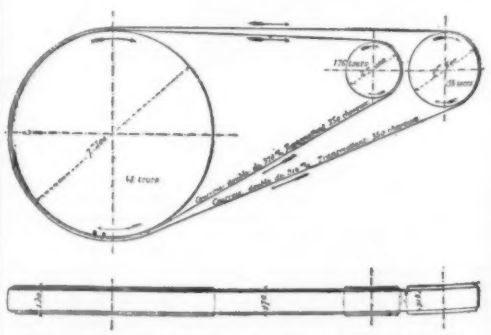
We hear that this exhibition was visited by over 70,000 people during the eight days on which it was open.—*The Engineer.*

TRANSMISSION BY SUPERPOSED BELTS.

MR. PAUL SEE, a civil engineer, has recently made a communication to the Industrial Society of the North of France upon a new method of transmitting motion by means of superposed belts. The application was made in the works of Messrs. Baertsoen & Buysse, of Gand.

In these works, there was at first merely a power loom actuated by a 350 horse power Corliss engine, by means of a belt thirty-six inches in diameter. To this was annexed a cotton spinning frame of 18,000 spindles that necessitated an equivalent power, and, in order to obtain this, a compounding of the engine was decided upon. But, in order to transmit this new power, there was a difficulty to be overcome. The belt guide had been constructed for but a single width of belting, and it was impossible to widen it, and, on another hand, it would have been necessary, in order to answer the new requirements, to change the shaft and arrange a new fly wheel, which would have occasioned great expense and too long a stoppage.

As the fly wheel of the simple engine was sufficient



TRANSMISSION BY SUPERPOSED BELTS.

for the compound one, Mr. Baertsoen conceived the idea of superposing the belts upon the fly wheel and arranging a second shaft in the interior of the first belt.

This arrangement fully succeeded, and has been in operation for a year without giving rise to any difficulty. The two belts have a stronger adhesion than if they were simple, they cannot slip on each other, and they produce no wear. The belts are of the Sampson

type, with juxtaposed bands and canvas center. The inner belt is connected by Harris hooks, and the outer by a bolted steel plate with double lap.

According to the *Bulletin* of the Industrial Society of the North, the following are the principal dimensions of the belts and the engine:

Small cylinder	28	inches.
Large cylinder	44	inches.
Stroke	59	inches.
Revolutions	48	
Pressure in small cylinder	108	lb.
Fly wheel: diameter	23·5	feet.
Fly wheel: width	3·25	feet.
Inner belt: distance from center.	27	feet.
Inner belt: width	38	inches.
Outer belt: distance from center.	35	feet.
Outer belt: width	35	inches.
Inner pulley: diameter	6·5	feet.
Outer pulley: diameter	7·5	feet.
Velocity of driving shafts	176 and 135	revs.

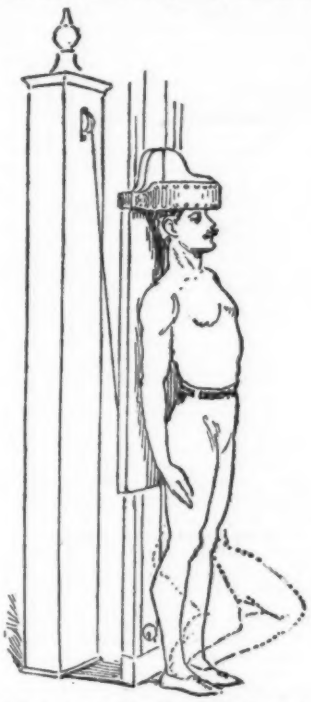
We have here an interesting application, which is capable of being generalized.—*Le Genie Civil.*

[Continued from SUPPLEMENT, No. 690, page 11028.]

[FROM THE BOSTON HERALD.]

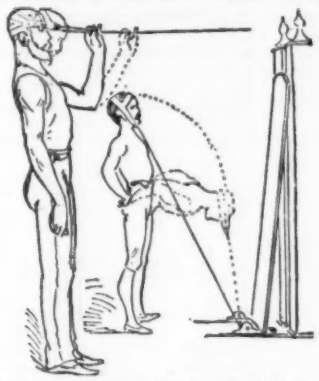
GYMNASTIC EXERCISES AND APPARATUS.

SPECIALISTS in all departments of the sanitary gymnasiums of the present day have become a necessity, because the gymnasium has become one of the great institutions of the times, a necessity of the age, a conservator of public health. Under medical and physical directions and examinations the work in all first class gynasiums is carried on, because the physical condition of men must first be ascertained before an intelligent course of exercises can be applied, in order that the best results from the applicant's work may be secured.



Head, Back, Arm, and Leg Machine, for Developing Erect Military Carriage.

The heart is the head of the muscular system, and is, of course, the most important organ of the body. While the condition of the muscular system is an almost sure index of the heart's condition, an examination of the fountain head of the muscular system is the only true test of a man's vitality or power to withstand the demands of the age. For this reason a stethoscope in the hands of a medical expert is indispensable to the examination room of the gymnasium, because a man's condition must first be ascertained before his work can be prescribed. In addition to the stethoscope, the ordinary measuring tapes and calipers are of importance in assisting the examiner in his work, and for that reason these articles of medical and gymnasium



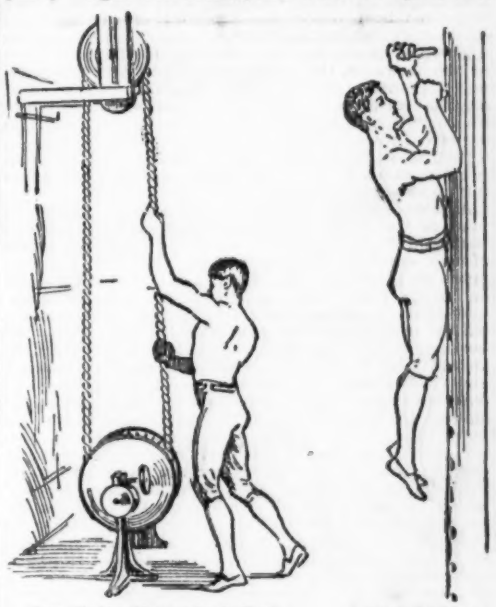
Back of Neck, Small of Back, and Leg Machine; Correcting Drooping Head and Strengthening the Back and Legs.

examining furniture are required. By the stethoscope the condition of the fountain head of the muscular system and the lungs is ascertained, by the tape the flexibility and expansion of the chest and the muscular measurements of one's body are learned, and by the calipers the diameters of the chest and proportions of the thorax are found out. On examination, if a man's general condition is found to be poor, the prescribed gymnasium work that is given him is light and graded to his needs; if he is in normal condition, but his proportions are not symmetrical, the work given him is of a special nature, to bring about a well rounded form and erect carriage; if his form is good and his condition normal, he is given a course of general exercises that will develop all parts in an equal manner, and give him perfect health, increased strength and greater endurance. Nearly every man who attends a gymnasium needs some special exercise or exercises for the development of a part or parts of his body, and for these exercises the gymnasiums of the present day are stocked with an endless variety of devices for bringing about the desired results.

Upright Wrist and Body Bar; Building Muscular Chest, Waist, and Loins.

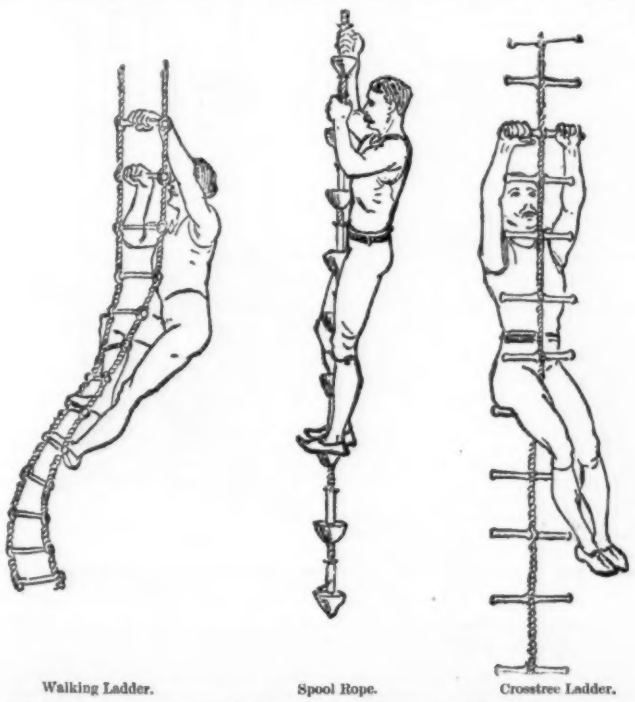
Among the many queer-looking and beneficial pieces of special gymnasium apparatus that an occasional visitor to a hall of health is almost sure to notice and look upon with some degree of interest, is the head, back, arm, and leg machine. This machine is one of the most useful for its purposes of any special apparatus employed for body building in any gymnasium of the land, and its working is so novel and so direct on the parts one desires to develop, or exercise, that it accomplishes its work by tiring the operator before practice on it becomes monotonous. The machine can be described as an upright plane about five feet high and one foot wide, made so as to slide up and down on two runs about eight feet high. From the top of the plane a cap or head gear protrudes outward. The operator puts his head under and in this cap or gear, facing out, with his back against the upright plane, feet close up to the bottom of the two runs, and hands down straight by his side, clutching, if he so desires, two pins which can be so arranged as to protrude from the plane on either side of the body at a point about where the hands reach. Standing in this position, the operator bends his knees outward till he comes within a few inches of sitting on his heels while standing on his toes. As he bends to this position, the plane with its loaded head rests and weights slides down with him. He must now come to an erect position again, and in order to do so is obliged to push up the top of the plane resting on his head by the power of his lower limbs. As he draws his knees in, he should stand on his toes and reach up as far as possible, making himself as tall as he can, thus bringing into play those muscles that help to hold an erect military carriage.

This exercise is no easy task, as a rope line attached to the back of the plane connects with weights in a pulley weight box behind, and when the operator is endeavoring to straighten himself out from his sitting posture, he is obliged to lift on his head by the aid of the muscles of his lower limbs not only the weight of the plane and head gear, but also the weights in the pulley box behind. These weights in the pulley box are always suspended when the operator stands in an erect position, with back against the plane and head under the extending cap above, and, of course, they have the effect of pulling the plane back to the



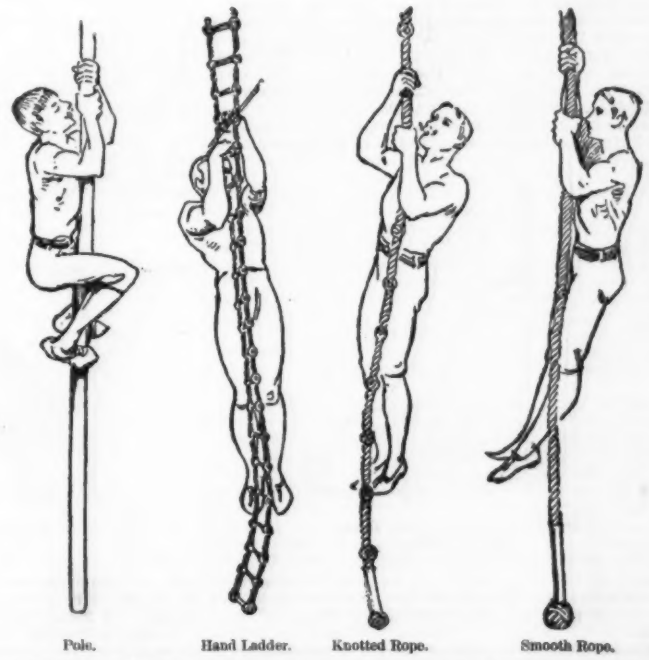
Rope Climbing Machine for the Weak; Strengthening the Back Muscular Chest.

Peg Pole Climbing.



Walking Ladder. Spool Rope. Crosstree Ladder.

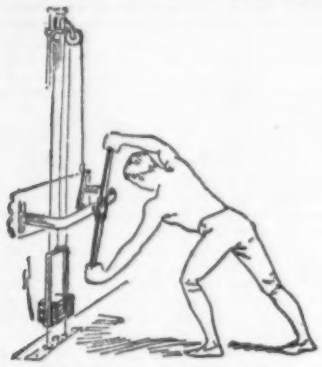
PRIMARY GRADED CLIMBERS FOR MUSCULAR CHEST AND ARM DEVELOPMENT.



Pole. Hand Ladder. Knotted Rope. Smooth Rope.

ADVANCED GRADED CLIMBERS—A STRONG MAN'S WAY OF GETTING EXTRA MUSCULAR CHEST DEVELOPMENT.

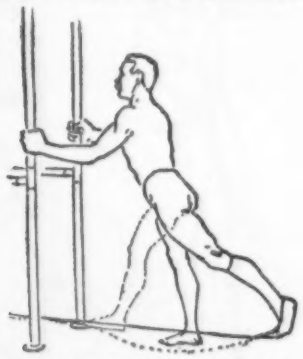
floor and giving quite a strain to the muscles of one's back and legs even while the operator stands under the cap piece of the plane without exercising. Pushing this plane up with weights attached, and letting it come down in the manner described, helps to correct some kinds of spinal curvature, builds up some of the muscles of the back, makes a man erect, and strengthens nearly all the muscles in the lower limbs. This piece of apparatus has been a good friend to many a man who has tried a civil service examination for



Wrestling Dummy; Building up the Loins and Upper Body.

either the police or fire department of the city of Boston, and failed to qualify for the reason alone that he was an inch or a fraction of an inch under the regulation height. Without changing his position, if a man takes his head out of the cap, and rests this cap on his fingers behind his neck, then pushes the cap as high up as he can reach, he develops the flexor muscles of the fore arm, the triceps or extensors of the arm, and the muscles that raise the arm, and also the muscles that raise the shoulders, if he puts extra effort into his reaching. The latter exercise, however, should be omitted in cases where the muscular attachments on top of the shoulder blades have become too large from practice at old style of gymnastic exercises, like pushing up heavy dumb bells.

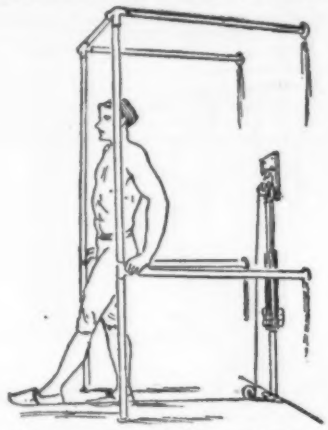
A piece of apparatus which, in a measure, takes the place of the above machine, and develops the muscles that hold the head and body erect, known as the "back of neck, small of the back, and leg machine," is a very much simpler appliance, and is available for the same and other special uses. Instead of the movable plane, a stationary vertical backboard is used in front of a pair of ordinary pulley weights, with floor pulley attachments. The lines passing under these floor pulleys are attached to an ordinary canvas and leather cap, made to fit over the operator's head. The operator, who stands against this vertical backboard as he did against the movable plane, and raises and lowers his body in the same manner, sliding up against the stationary board, gets a free and much more natural exercise than that afforded by the plane machine. This simple machine can be used in a different way, by facing the pulley weights and placing the cap at the end of the pulley lines, running from the pulleys on the floor over the top and back of the head, standing erect and then allowing the weights to pull the head and bend the body forward and down, thus stretching and developing all the muscles in the posterior part of the body. By coming to an extremely erect posture from the bended position, still facing the pulleys, all the erector muscles of the spinal column are developed, and the back is given a general strengthening and straightening. If the operator desires to only bring into play the erector muscles of the cervical and upper dorsal region, or cure drooping head and neck by the use of this machine, he stands with his body erect, facing the machine two or three feet away, as in the previously described movement, and allows the weights in the pulley box to pull his head forward and down. He then pulls his head back to his former erect position, keeping his chin well in and getting resistance from the weights in the pulley box, which resistance brings about the muscular action in the deep-seated muscles of the back of the neck which hold the neck and head erect. Some of these machines are so arranged that the pulley lines attached to the cap have the pulleys at the top of the machine instead of a pulley on the floor. These machines serve the purpose of confining the action almost entirely to the region about



Flexor Shoe; Developing Back Muscles of Thigh and Hip.

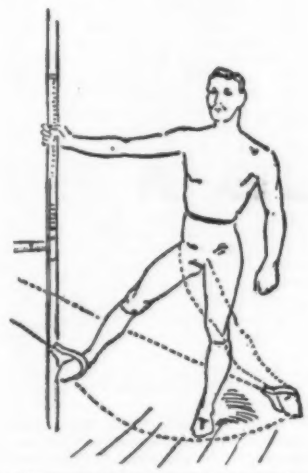
the back of the neck, and are invaluable to sedentary workers who stoop their heads over books or desks and need an exercise to counteract the ill effects of such habits.

A special piece of apparatus for the development of the wrists, fore arms, and portions of the upper body in one series is the so-called upright wrist and body bar, which is as useful as it is ornamental. It differs very little in appearance from the horizontal wrist machine illustrated in SUPPLEMENT of last week, though it serves a much different purpose. It is a graduated pin, about four feet long, set in an upright position, with the lower and larger end set about 2½ feet above the floor. This end is about six inches in diameter, while the smaller or top end is but two inches in diameter. A rope attached to pulley weights runs around part of the larger end of the pin and furnishes resistance. The operator clutches the bar in his hands and twists and turns it, while resistance is being offered by the weights which are drawn up in the pulley box as the pin moves around. This twisting movement has the effect of improving the operator's



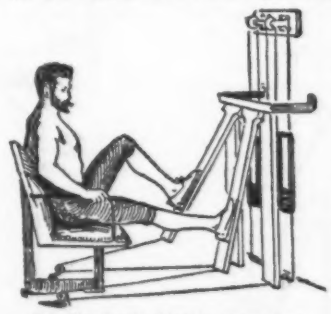
Flexor Shoe; Developing Extensor Muscles of Thigh and Internal Abdomen.

grip, and induces circulation in and develops the fore arm. It is a very valuable movement for those suffering from numbness of the upper extremities and penman's paralysis. If the operator drops the body toward the bar, takes a longer grip, and turns the pin, as shown in the accompanying cut, then comes to an erect position while still holding on to the pin, he develops the muscles in the upper part of the body and around the waist and loins. This movement can be varied by putting both hands on one side of the larger end of the pin, and so twisting the pin that the loins and sides are brought into play, and consequently developed in the effort.



Adductor and Abductor Machine; Strengthening Bow Legs.

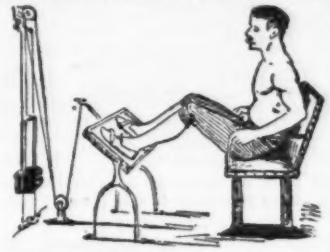
The rope climbing machine is an odd and very ingenious piece of apparatus for the use of the weakest of gymnasium attendants who desire to get the sensation of climbing a rope, and at the same time developing the muscular chest. This machine may be rightly described as an endless rope running over two round drums, or wheels, one wheel close to the floor and the other about eight feet high. The operator stands facing the rope, which is tightly drawn over the drums of both wheels, and reaching up hand over hand pulls the rope down as he would in hoisting merchandise up and out of a vessel, with his hoisting rope running over but one block above his head. A man who practices on this rope climbing machine develops almost identi-



Treadling Leg Machine, for General Leg Development.

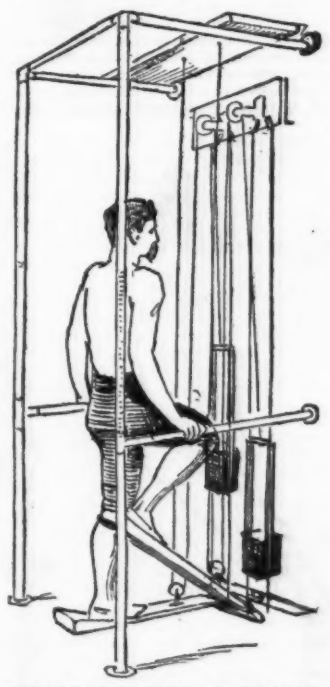
cally the same muscles as a man who turns the nautical wheel previously described in pulling down the wheel handles by facing the side to the wheel.

A strong, healthy, robust fellow may graduate with impunity from the rope climbing machine to the easiest of rope ladders, and then as he develops his aptness and strength for these ladders, he may promote himself from the easiest to the most difficult of ladders, finally ending with what is known as a smooth rope. The easiest of all these climbing ropes or ladders is the cross-tree ladder, made of a single rope, with small pins passing through it, fastened securely in the middle, and extending about six inches on either side. These pins are set about one foot apart, and the rope hangs from ceiling to floor. The operator grasps the ends of one of these pins with his right and left hands on opposite sides of the rope, and draws himself up, bringing into play and developing the front and back muscular chest, the biceps of the arm, and the muscular attachments of the shoulders. As soon as he draws himself up as far as he can in this manner, he raises his knees up and catches them over one of the pins below,



Foot Flexor Machine; for Muscles of Anterior Leg.

thus developing the muscles in the internal abdomen, as one does in raising his knees close up to his chin while lying down on the abdominal mat, a movement that is very often given for preventing and sometimes curing rupture, but which, if carried to excess, will pull down the floating ribs and front walls of the chest. With his knees over the pins on this ladder, the next movement the operator must make in order to renew his grip and climbing higher is to extend his thighs by bringing into play the heavy muscles behind the hips. A rope ladder that can be made easier or harder than the cross-tree ladder is the walking ladder or ladder of rope sides and wooden rungs, made after the style of the ordinary wooden house ladder. This ladder is for general exercise of an extremely difficult nature, which is afforded the person using it in the various methods of climbing with his hands and feet or arms and legs. It affords a great variety of test exercises. Next in point of difficulty to encounter in climbing is the spool rope, or single rope with hollow inverted wooden cones about four inches in diameter at the largest end, attached to the rope from top to bottom at a distance of about eighteen inches apart. This rope is climbed in the usual way by the power of the arms and muscular chest, assisted by the muscles of thighs and hips, which of course are developed by being brought into play. The cones furnish temporary rest for the operator, who may stand on them when he tires of climbing, or he may sit down on them, unless he happens to be bow-legged, or is in the habit of riding horseback, and got crooked legs, and cannot keep his legs together close enough to prevent the cones from slipping through them. Boys are positively forbidden the use of these ropes in all sanitary gymnasiums, because the ropes are too severe for youths to use, and for other reasons. A man who uses this style of rope will find it but a slight degree easier to clinch than the so-called knotted rope, or hanging rope, knotted at regular distances from floor to ceiling. These knots are made of heavy, hard twine woven into the strands and securely fastened around the rope, and they afford to the climber a slight rest for the feet when he tires, and a good place to grip with the hands while he is climbing. The exercise taken on this rope develops the same muscles as are developed by exercise taken in a similar manner on the other ropes, though it is not quite so severe as exercise in climbing the smooth rope or pole, both of which are



Upright Treadling Machine; for Developing Muscles Used in Running and Tricycling.

shown herewith, and it is slightly more severe than climbing the hand ladder. The peg pole is the most difficult of all pieces of climbing apparatus seen in the gymnasium. It is a large pole in which are bored holes about six inches apart, into which fit the pins which the operator grips and uses in climbing, holding himself by one hand while he removes the peg from one notch to another with the other hand, and so on till the top of the pole is reached. The movements on this pole demand remarkable strength around the shoulders and in the flexors of the arm.

For the reason that they tend to stiffen and over de-

velop the muscles around the shoulders and chest, exercises on the rope ladders and climbing machines should always be followed by reaching-up exercises, respiratory gymnastics and passive stretch and elongating exercises, such as are afforded by the use of the sternum elevator, traveling rings, and other similar apparatus. The wrestling machine is an ingenious device for the purpose of exercising and developing the muscles of the loins, back, forearm, and wrist. The machine is very simply made by attaching the end of a pulley rope to an iron arm which connects about three feet from the floor with the center of a round pin about two feet long. The operator grasps this pin with both hands, one each side of the center, and turns it toward the right or left, as he desires, or even completely around while holding on to it. As he turns the stick or pin, the weights of the pulley are drawn up, and offer resistance to the muscles brought into play in turning the handles or pin of the machine. Exercise on this machine is nearly of the same nature and develops the same muscles as exercise on the nautical wheel.

The gymnasium machines for the purpose of developing the muscles of the lower limbs are as simple and unique as they are useful. They are like many of the other kinds of special developing apparatus in use in a gymnasium, and can be made by applying some simple idea to the ordinary double action chest weights. The simplest of the lot is the flexor shoe for developing the back muscles of the thigh and hip. This machine is made by attaching a shoe to any ordinary chest weight pulley rope connected with weights, running through a floor pulley. The operator stands with his back against the machine, puts his foot in the shoe, and moves it back and forth as if he was wading in water, holding a stiff leg. As he pulls the shoe from the machine the weights ascend, and as he allows his foot to come back to position the weights descend. If the operator desires to develop the extensor muscles of the thigh and the internal muscles of the abdomen, he must face the weights, reverse the shoe, tying it by the toe to the weight rope, instead of tying it by the heel, then put his foot in the shoe, and draw his foot from the machine, allowing his foot to be drawn back into position by the weights descending in the slide or box. If one desires to develop the adductors or abductors of the leg, all he needs do is take off the handle of one of his pulley weight machines and attach to the pulley rope a strap, through which he can put his foot, then facing right side to the machine, if he draws his right leg out and over the left leg, he develops the muscles inside the right leg. If he stands with left side to the machine, he develops the muscles on the outside of his right hip and thigh, that is, if his right boot is in the strap. The same motions can be gone through with the left leg through the strap with the same results on the muscles of that leg, the muscles on that side of the leg farthest from the machine always being developed when the operator draws the strap out and the weights ascend in the pulley box. For the purpose of developing the back and front legs and thighs, what is known as a treadling leg machine is used in a gymnasium.

The workings of this machine, and also the machine known as the foot flexor, will readily be understood by studying the cut of both machines shown herewith. In the treadling machine the operator sits in a chair and pushes down the treadles attached to the weights in the pulley box, thus drawing the weights up. As the weights return to the floor the treadles rise from the floor, where they were pushed by the operator, and then the operator again forces them down. In this manner not only the muscles of his legs are developed, but his digestive organs are brought into play. The foot flexor machine is worked by lifting up with the front part of the foot a board foot rest, which is connected by a rope with weights. As the rest is lifted the weights are drawn up, and as the rest descends the weights drop back to the floor.

Practice on this machine develops the muscles on the front part of the lower leg.

The so-called treadling machine is made after the same pattern as the leg treadling machine, and is worked in much the same way as the latter, excepting that a man stands up instead of sitting down in doing his treadling. Practice on this machine develops the same muscles as a man develops in tricycling and running.

These various machines make an interesting study, even for the occasional visitor to a gymnasium who does not engage actively in their use.

(To be continued.)

BISULPHIDE OF CARBON.

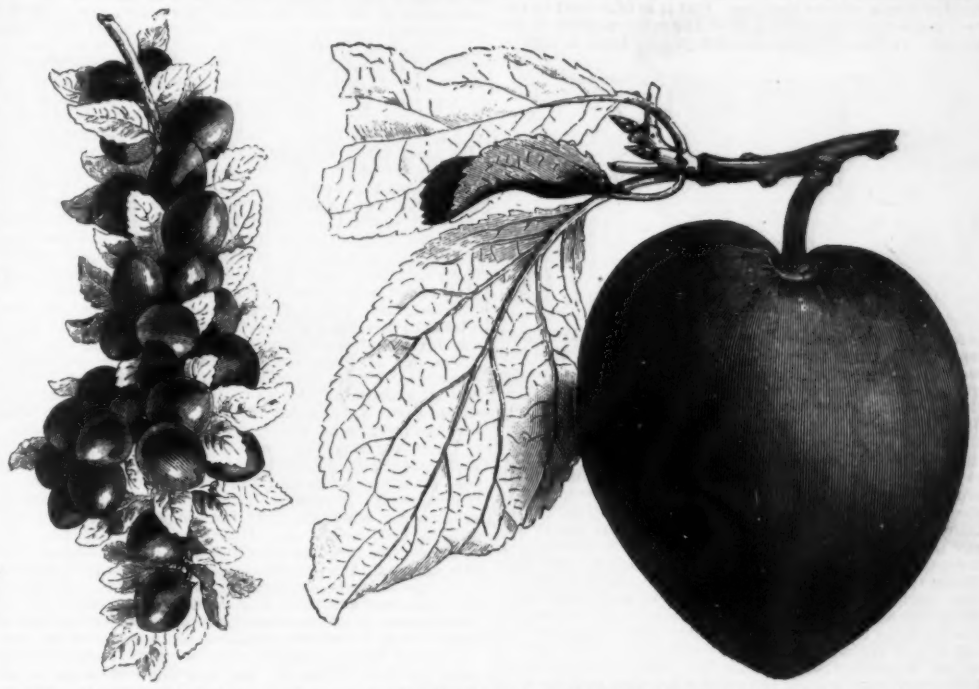
MR. IGNATIUS SINGER read a paper before the Manchester Society of Chemical Industry on "The Manufacture and Purification of Bisulphide of Carbon." He described in detail a method of manufacturing bisulphide of carbon in vertical cast iron retorts about 6 feet high, oblique in shape, with an internal diameter of 20 in. by 12 in. The product obtained by the process contained, he said, considerable quantities of sulphur solution, and a large amount of H_2S and other sulpho-compounds, which gave it a pale yellow color and a very disagreeable odor. From these impurities it could be easily freed by careful rectification, leaving a colorless, mobile liquid of an odor not at all disagreeable. Commercial CS_2 was seldom pure, and in many instances differed from the crude substance only in containing a less quantity of free sulphur. Many methods had been described for its purification. He had employed the following simple process with very satisfactory results. A cylindrical vessel, about 30 in. in diameter and 6 ft. high, was provided with a perforated coil of lead pipe at the bottom. Into this vessel he ran the CS_2 to be purified to about one-third of its height. He then pumped lime water into it, this being introduced into the vessel by means of a force pump through the perforated coil. The lime water, being specifically lighter than the CS_2, rose to the surface, and while traversing the body of the bisulphide in a finely divided spray, the lime combined with the H_2S, etc. He continued this washing until the lime water, which left the vessel through an overflow pipe near the top, was perfectly clear. The CS_2 was now run into a still, about one per cent. its weight of a cheap colorless oil added, and covered with a layer of about 1 inch of water, to which sugar of lead might be added. The CS_2 was now distilled in a water bath and condensed in the usual way. A very pure product was obtained in this way. He had treated in this way CS_2 bought from a Manchester maker, which was supposed to be "rectified." Its sp. gr. was 1·292. After having washed it in the above manner it had a sp. gr. of 1·286, after distillation, and differed from the crude substance only in having a less proportion of free sulphur.

THE KELSEY PLUM.

THIS Japanese plum, which has for some years past been rather extensively grown in California, appears to possess qualities which should strongly recommend it to the notice of the British fruit grower. For the following particulars respecting it, as well as for the accompanying illustrations, we are indebted to the *Revue Horticole:*

The Kelsey plum is a wonderfully productive kind, not surpassed in this respect by any other known variety. It commences to bear fruit in the second or third year after grafting, and very often shows some flowers in the first year. The fruit attains a very large size, sometimes being nearly 9 in. in circumference. It is also very pleasing in appearance, being of a lively yellow color, tinged with deep red on the side exposed to the sun. In form it is heart shaped. The flesh is of excellent quality, melting and very juicy. The fruit is firm in texture, and so can be sent in good condition to distant markets.

The Kelsey plum also appears to thrive in Florida, judging from the account given by Mr. Taber, of Glen St. Mary's, in the *Florida Dispatch* of 1887. In February, 1885, Mr. Taber planted six very weakly specimens which had been grafted in the preceding year. In June, 1887, that is, two years after transplanting, one of these trees was carrying 467 plums as big as hen's eggs. The illustration here given represents a branch of one of these young trees laden with fruit. Another branch bore sixteen plums, the average weight of which was nearly five ounces. One of these plums



FRUITING BRANCH OF THE KELSEY PLUM.

KELSEY PLUM (SHOWING FRUIT NATURAL SIZE).

weighed 5½ ounces, and measured 7½ inches in circumference. This plum is represented in the illustration above. It has been observed by Mr. M. T. K. Godbey, another cultivator in Florida, that the Kelsey plum proves more vigorous and productive when grafted on the plum stock than it does when grafted on the peach.

From the foregoing it may be gathered that the Kelsey plum is a very desirable variety, and as it is largely and successfully cultivated in California, there seems to be no reason why some of our own fruit growers also should not give it a trial.—*The Garden.*

METEORITES AND THE HISTORY OF STELLAR SYSTEMS.

A LECTURE on "Meteorites and the History of Stellar Systems" was recently delivered by Professor G. H. Darwin, at the Royal Institution. He first explained that such great advances had recently been made in celestial photography that now, by using very sensitive plates and giving an exposure of some hours' duration, photographs could be obtained showing stars too faint to be seen by the eye with the aid of the telescope. A photograph of this kind (a portion of the milky way in the constellation *Cygnus*) was exhibited.

In the vast multitude of visible stars, representatives of every stage of evolution are to be found, and by means of the spectroscope it is possible to ascertain approximately their age and temperature. Coming to the question of their formation, the lecturer explained the nebular hypothesis of Laplace, which would account for the formation of planetary systems, in a very plausible manner. Assuming a mass of gaseous matter at a high temperature to be revolving round its axis in space, the form assumed by it would be that of a sphere flattened at the poles and bulging at the equator. As cooling took place on the outside it would be accompanied by condensation, and this would cause more rapid revolution, and increase the centrifugal force and consequent bulging at the equator. At a certain stage the centrifugal force at this point would overcome that of attraction, and a ring of matter would separate off at the equator and revolve outside the central nucleus. This ring on further cooling and condensation would aggregate into masses or planets revolving in orbits round the central mass, while in this still contracting central portion the same process would be repeated, giving rise to another series with smaller orbits. In this way a planetary system would be produced, revolving round a central sun.

In support of this hypothesis, the lecturer showed on a screen a very fine photograph of the nebula in Andromeda, taken for him by Mr. Roberts, and showing a central mass of more densely aggregated matter surrounded by several rings of nebulous matter which presented distinct centers of aggregation into smaller nuclei or planets; it showed just the appearance deduced from the hypothesis.

There is, however, one grand obstacle in the way of the acceptance of the nebular hypothesis. Recent observations and deductions made by Lockyer, Maxwell, and others tend to prove that nebulous matter is not gaseous, but made up of solid fragments, a shower of brickbats as it has been called, by the frequent collisions of which sufficient heat is produced to temporarily convert portions of them into vapor so hot as to be incandescent. These incandescent gases would rapidly cool, but as the collisions would be incessant, more would be continually produced. This seems totally opposed to the nebular hypothesis, as the essence of the latter is that the matter is gaseous.

The chief object of the lecture was to indicate how this theory of Lockyer's may be reconciled with the nebular theory of Laplace, which is so satisfactory in other respects.

To begin with, the lecturer explained the kinetic theory of gases, aptly comparing the colliding and rebounding molecules of a gas to the movements of a swarm of house flies. If his audience could imagine themselves reduced to immeasurably small dimensions, the molecules of air would appear to them as so many cannon balls rushing about in all directions with great velocity. Now returning to nebulæ, he held that these were so vast that the meteorites of which they consist, according to the theory of Lockyer, may be regarded as equivalent to the molecules of a gas.

The necessary elasticity to cause them to rebound from each other after collision would at first sight appear to be wanting in solid bodies, but the result of their impact at so enormous a speed would effect such a development of heat that portions would be volatilized into vapor possessing a high temperature, and this would have an effect similar to the explosion of a charge of gunpowder between them.

Having disposed of this difficulty, another remained, viz., the frequency of fracture; it would naturally be supposed that by all these collisions the meteorites would ultimately be all broken up into dust. This, however, would probably not be the case, for the volatilized portions on cooling would condense into a kind of rain which would fuse with previously formed meteorites, and so balance the effects of fracture. As a matter of fact, many meteorites show marks of this fusion.

The lecturer then proceeded to support the possibility of his theory by figures, taking our solar system as a basis and imagining its mass to be scattered in fragments of a pound each through a sphere with a radius twice the distance of Neptune from the sun. The number of these masses would be represented by 4 with 30 ciphers after it, and he gave figures to show that the collisions between them at any distance from the center would be sufficient to support their analogy to the molecules of a gas, and reconcile them with Laplace's hypothesis.

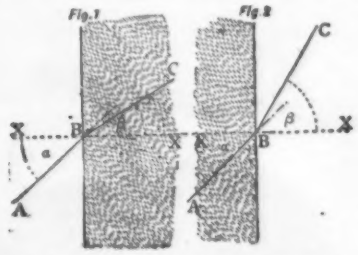
The formation of planets was also readily explicable, for as the meteorite masses became more crowded together in the centers of aggregation, their velocity and the length of their free paths would diminish, and as the impacts became more frequent the gases generated would not have time to cool down, and there would result a central mass surrounded by incandescent vapor. With this theory, too, many other known facts accorded, such as the presence of the large number of asteroids between the orbits of Mars and Jupiter. Other rings of similar asteroids probably existed, but

not in so favorable a position for being seen, as any occurring between the orbit of Venus and the sun would be too near the latter to be visible, while any outside the orbit of Jupiter would be at too great a distance. The zodiacal light was very probably a reflection of the sun's light from a group of meteorites in its neighborhood, and the showers of shooting stars which periodically visit us constitute some of the dregs of our solar system.

THE CONSTRUCTION OF PHOTOGRAPHIC LENSES.*

By CONRAD BECK.

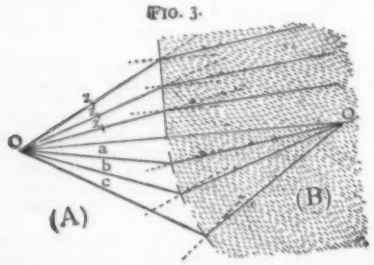
THE theory which has explained the majority of the phenomena of light is that it is produced by vibration in a medium we call ether, which is assumed to permeate everything. Although this theory may be superseded—or more correctly, developed—it is quite sufficiently certain for us to accept its results for the purposes of this paper. The vibration is held to be a wave motion which takes place at right angles to the direction in which the light is moving. The distance between two consecutive crests or hollows of the wave is termed a wave length. This wave length does not depend on the intensity of the light, and for the same colored ray it is always the same when traveling through the same medium. But should this ray pass into another substance of greater density—as, for instance, from air into water—its wave length will be shortened, and will give rise to the phenomena called refraction. Without, however, entering fully into the causes, let us merely examine this fact we call refraction. We can at once see, by the very simplest experiments (as, for instance, placing a stick in water), that the light which comes from an object in a denser medium is bent on its journey, and as rays of light in one medium alone are experimentally proved to move in straight lines, this alteration of direction or refraction must take place at the surface of the two media. Precisely the same result ensues when light passes from a lighter into a denser medium. But it is observed in the two cases that the direction of the refracted ray is different. In Fig. 1, where the ray passes from a lighter



into a denser medium, it will be noticed that the refracted ray turns toward the perpendicular to the surface which divides the media, while, when it passes from a denser into a lighter medium, it turns away from this perpendicular, or the normal, as it is called. We find, by experiment, that if we take the ray which cuts the dividing surface at right angles, it will pass direct into the second medium without refraction, and that rays which impinge on this surface at different angles are refracted to a different extent. It only remains to discover whether there is any law which these refractions follow which can determine at what angle any ray will emerge in a given medium, when entering it for another given medium. It is curious to find that Ptolemy, in the second century, made observations of the angles of incidence at a surface, and their corresponding angles of refraction. Vitello, a Polish mathematician, in the thirteenth century, did the same, but the law of refraction was not discovered until 1621 or so, by Willebrod Snell. This law (which is established by experiment) states that when we are dealing with two media of different density, the sine of the angle of incidence divided by the sine of the angle of refraction is equal to a constant quantity, which is called the index of refraction; and it was also observed that the incidence and refracted rays lie in one plane. The angles of incidence and refraction are the angles which the incident and refracted rays make with the normal; thus, in Figs. 1 and 2, the angle of incidence is the angle ABX (α), and the angle of refraction is the angle CBX (β).

Let us now consider light coming from a point, O, in one medium (A) Fig. 3, say air, and entering

FIG. 3.



another medium (B) which we will suppose denser, say glass. Light will impinge on the dividing surface, which for the first case (upper portion of Fig. 3) we will consider flat, at all angles. Let us first note, as we said before, that the ray which strikes the surface at right angles goes through it without refraction. All other rays will be more or less bent, and the law of refraction shows us that those in which the angles of incidence are greatest have greater refraction in proportion than rays of smaller angles of incidence, for if we differentiate $\frac{\text{Sin } \alpha}{\text{Sin } \beta} = \mu$, we shall see that as the angle of incidence is increased, the amount of refraction, or the difference between β and α, is increased much more rapidly. In the second case, suppose instead of a flat surface we take a series of small facets and place them at right angles to each ray, then these rays will all pass through into the glass without refraction; thus, if we have light coming from the center of a circular surface, it will pass through it without refraction.

Next (Fig. 3, lower portion) let us place our series of facets in such positions that, instead of destroying the refraction of the several rays, we increase it. Let us do this to such an extent that, instead of having a diverging series of rays, we make them converge toward the axis. Now, by properly arranging our plates we can make the three rays, *a*, *b*, *c* (Fig. 3, lower portion), converge to the same spot. But since the number of rays is infinite, we shall need to place a series of plates so small as to be merely points. These points will trace a curve, and the form of this curve will be the necessary shape of the dividing surface of the two media, in order to cause a bundle of rays proceeding from a point, O, to converge to some point, O', in the denser medium.

Now this is just the proposition we have in photography. It is required to converge the light emerging from one point of the object to a single point on the photographic plate; but as a rule the object is at infinity, and light impinges on the surface in a parallel bundle. The practical photographer must not be misled by this word infinity; it is a relative term, and a distance of twenty feet, for instance, when compared with a distance of two or three inches, is practically at infinity, *i. e.*, we can treat all light which starts from such a distance as traveling in parallel rays. Now the curve which would bring parallel rays to one single point is a conic section, and Descartes showed that if lenses could be made whose sections were ellipses or hyperbolas, they would accurately accomplish this. But, alas! all practical men know that it is impossible to make these surfaces true enough for optical work. One true surface we can make, and that is a spherical one, and this is the one which, for want of a better, we are obliged to adopt. To make it clear why a parabolic or elliptical surface cannot be made, I will merely draw your attention to the fact that, in order to grind or polish a lens surface, a tool must be made of the exact shape of the lens required, the lens must then be ground with emery or some other material until the glass assumes precisely the shape of the tool, and in order to accomplish this it is essential that the glass be moved over the tool in several directions, and that it is at the same time touching the tool over its whole surface during the operation. In practice it is found that the more irregular the motion within certain limits, the more likely the surface of the glass is to be ground equally all over. As an example, let us suppose we wish to make a lens of elliptical shape; the only way in which the glass can be moved in the tool while it remains in contact over its whole surface is by its being revolved on the axis of the ellipse. It is evident that if this be done, as the periphery moves more rapidly than the apex, more will be ground off the edge than the center, and a true curve cannot be obtained.

What, now, is the effect of using a spherical surface? The rays no longer all meet at one point, and the larger the surface of the sphere we are considering, the more difference is there between the points to which they converge. The error which thus arises—due to the fact that it is necessary for us to use spherical surfaces—is called spherical aberration, and I propose to show what are the devices by which we reduce it to a minimum.

There are only two cases in which it is possible for us to obtain no aberration for light passing through one single surface, and both of these are useless for photographic purposes. The first case we have already mentioned, when the object is placed in the center of a sphere, but, as we saw, this gave no refraction; the second case is when the distance of the object from the center of the sphere is equal to a certain quantity, viz., the refractive index multiplied by the radius of the spherical surface. For photographic lenses the radiant point is almost always at a great distance, and its rays being, therefore, parallel, cannot enter any surface as if they emerged from a point comparatively near to the center of the spherical surface, as this would be.

I shall not weary you by going through the mathematical steps which determine the exact amount of aberration for rays due to refraction through a single surface, but the amount is given by the equation

$$\Delta f = \frac{\mu - 1}{\mu^2} (\rho + D)^2 \left\{ \rho + (\mu + 1) D \right\} \times \frac{y^2}{2}$$

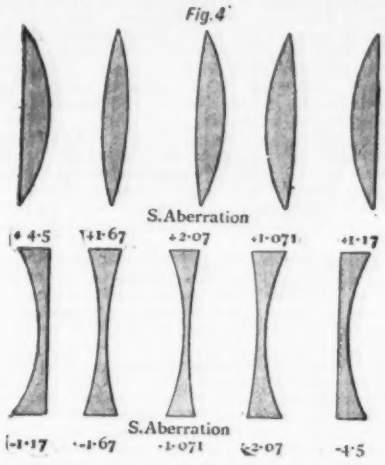
Where f is the reciprocal of the distance of the point to which the rays converge from the refracting surface, ρ is the curvature of the surface, y the semi-aperture, D the reciprocal of the distance of the radiant point from the surface, and μ the index of refraction. In dealing with this equation we must not take the absolute aberration, but take it with reference to the focus, and there is not time to-night to discuss the way in which it varies.

I have previously mentioned that in order to bring a bundle of parallel rays to a point, we require an ellipse or hyperbola; it should be the former when the rays enter a denser from a lighter medium. It is interesting in this connection to note that the most perfect projection lens in existence, the human eye, has for its first surface (the cornea) a portion of an ellipsoid, whose section would thus be elliptical.

We assume, therefore, that the nearer a surface tends toward the elliptical form, the less aberration it will possess, and it is evident that a convex surface is nearer to an elliptical form than a flat surface, and will therefore give less aberration, while at the same time it has greater refracting power. And we can further see that the nearer we make this convex surface approach the given ellipse (which is determined by the refractive index), the more we destroy aberration. If now we take two refracting surfaces and form what we call a lens, we at once ask ourselves, Can we not, by properly combining the two curves, destroy aberration entirely, and yet leave some refraction, for we see that the two do not vary in proportion? We find that we can make lenses of the same refractive power, but with widely differing aberration; but in spite of this, we cannot entirely destroy it, with the kinds of glass that we now possess. We should require a material with a refractive index of at least 4, the possibility of discovering which is altogether beyond our most sanguine hopes.

It is therefore impossible to entirely correct aberration in one lens. We can, however, largely modify it. I have made a diagram showing the relative amounts of aberration which arise from lenses of various shapes, and you will see that the lens with the greatest amount of aberration possesses four times that of the best form. As a general rule, we can remember that when parallel rays enter from a less refractive medium—say air—into a denser medium, such as glass, the more curved the surface turned toward the parallel

Fig. 4.



rays, the less the aberration; the flatter the curve, or the nearer it approaches a flat surface, the greater the aberration.

I have placed at the top of this diagram a series of convex lenses, all of the same focus, giving their aberrations, and below them a series of concave lenses, also of the same focus (only negative), giving their aberrations. If, now, we take a convex lens and place it next to a concave lens, with just the same relative aberration, we shall neutralize the aberration; but since the focus is the same, the refracting power will also be destroyed, and the compound lens will have no power to affect light passing through it. But suppose we take a convex lens with the smallest amount of aberration, and combine it with a concave lens of the largest quantity of aberration, although we get the refraction neutralized, we shall get the aberration far more than corrected, and can reduce the focus of the concave lens, and with the focus the aberration, which is dependent on the focus, to such an extent that the aberration is corrected, and we shall then have left a considerable amount of refracting power, although, of course, not so large an amount as in a single convex lens.

Let us then see to what conclusion we have arrived. We have found that light is bent on entering a medium of different density, that we can nearly bring this to a point, but not wholly, by a single spherical surface; that a lens will, to a certain extent, correct the error thus formed, but not altogether, but that a combination of two lenses will completely do so.

We have hitherto treated light as if it were caused by a single vibration of the material we call ether, this vibration having always one wave length, which is only altered when the light passes from one medium into another of different density. This, however, is not the actual fact, though in order to explain spherical aberration it was convenient to assume that such was the case.

The effect which gives rise to the sensation of white light in our eyes is supposed to be produced by the combination of a large series of vibrations all acting together on the retina of the eye. If we consider a vibrating ray emerging from the sun or some other powerful light-giving source, we shall find that it consists not of one vibration with a single wave length, but of a great number all traveling together at the same rate, and differing only in their wave length. On more close examination of this ray we shall find that the vibrations consist of some with a long wave length, others with a slightly shorter wave length, others again still shorter, until we have vibrations with exceedingly short waves. In fact, the complete ray consists of an ascending series of vibrations, each having a slightly shorter wave length than the last, and all traveling together.

It is interesting now to see in what ways these various vibrations affect our different senses. If we isolate from a complete ray the waves only that have very long wave lengths, we shall find that no effect of light is produced on our eyes; but if we place a thermometer in the path of these rays, we shall observe that these long wave length vibrations have heating power. Let us now isolate a portion of vibrations with rather shorter wave lengths; we shall find that the effect of heat is still produced, but that our eyes are also affected by these rays, and the result obtained is that we see what we call red light. Isolating again another portion of the vibrations with still shorter wave length, the effect they produce on the eye is again light, but of a different color—yellow. The next vibrations produce the colors to the eye of orange, green, blue, and violet, in the order of the spectrum, until at last we come to a point where no further effect of light is produced. The vibrations do not, however, cease here. There are vibrations with still shorter wave lengths than those which cause light, and these, together with the green, blue, and violet vibrations, are the waves which affect the photographic salts of silver.

One must not suppose that there is any radical difference between these rays beyond the difference in their wave length. They affect our different senses in different ways. The vibrations that are beyond the visible end of the spectrum would give rise to light, except that our eyes are not delicate enough to see them. We have every reason to believe that they are visible to some of the smaller animalcules.

The same applies to the heat rays, and if our eyes were but sensitive to them, we can conceive it possible that we should have no need to ask our companions in the room if they found it too warm; we should see if they did so.

Let us now retrace our steps. You will remember that refraction is due to the fact that the wave length of light is altered by passing from one medium into another of different density. This light, however, does not consist of one vibration, but of a series of vibrations,

* A paper read before the Society of Arts, London. From the *Journal* of the Society.

each with a different wave length, and it is a fact proved by experiment, and accounted for by theory, that these vibrations have their wave lengths altered in passing from a rare into a denser medium in a different manner.

We have shown that it is possible to construct an optical system which will refract a bundle of parallel rays to a single point, but in doing so we have assumed that the light was caused by vibrations of the same length, namely, that it was of the same color. The rays, however, have not the same wave length.

This defect, namely, that a bundle of white light entering a lens does not come to the one point, owing to the fact that light of different colors is refracted to different extents, is called chromatic aberration, and the correction of this error is one of the most important of the optician's duties. The amount of the difference between the refraction of the extreme colors when passing through a glass is called the "dispersion" of that glass. Glasses can be made which have different refracting powers, and with the difference of the refracting power the dispersion generally varies. If the dispersion of these glasses were always in the same proportion to their refraction, it would be impossible to correct for this aberration, for suppose we have a convex lens which has a dispersion one-tenth that of its refracting power, by which I mean that if it brings the violet portion of a bundle of parallel rays to a point nine inches from the lens, it will bring the red portion to a point ten inches from the lens, and suppose we place a concave lens in front of this convex lens, which will give us exactly the same difference in the refraction of the different colors (but being concave it will be in an opposite direction), then if the amount of the dispersion of this glass is also one-tenth of its refraction, we shall, in order to neutralize the dispersion of the convex lens, require a concave lens of exactly the same focus, and shall also neutralize the refracting power of the combined pair, and the compound lens no more acts as a lens, but as a parallel plate of glass.

It is found, however, that glasses can be made which have different degrees of dispersion in comparison with their refracting power. In general the more highly refractive glasses have a higher proportional dispersion. We might perhaps find, for instance, that a glass had a dispersion equal to one-fifth of its refraction, instead of one-tenth part.

If, then, we make our convex lens of a glass that has a dispersion only one-tenth of its refracting power, and make our concave lens from the glass which has the higher dispersion equal to one-fifth of its refraction, we shall find that the latter will only require to be half as powerful in order to correct the dispersion of the original lens, and although it will have neutralized by one half the original refraction, there will still be left remaining a power equal to half that of the convex lens. Thus, for the correction of chromatic aberration, it is important to note that the only essential condition is that the foci of the two lenses should be proportional to the relative dispersion. If one glass has a dispersion of one-tenth of its refraction, and the second glass has a dispersion of one-fifth of its refraction, and if we make a positive or magnifying lens out of the first glass, and a negative or diminishing lens out of the second glass, provided the first lens has a refracting power double that of the second, the chromatic aberration will be corrected, no matter what the shape of the lenses; and it is evident that by altering the curves of the lens, but always having the same balance between the two curves, either of the lenses may be made in many different shapes and yet give the focus required. Thus the correction for achromatism depends not upon the shape of the lens, but on the foci of the two component lenses, while, as we saw before, the correction for spherical aberration depends not upon the foci of the lenses, but upon their relative shapes. There is therefore no difficulty in correcting for both spherical and chromatic aberration in the same pair of lenses.

The formula, the conditions of which must be fulfilled in order to obtain an achromatic pair of lenses, is a simple one, and runs as follows:

FORMULA A.

$$\frac{\varphi_1}{\varphi_2} = \frac{\left(\frac{\mu - 1}{\Delta\mu}\right)_1}{\left(\frac{\mu - 1}{\Delta\mu}\right)_2}$$

When φ_1 φ_2 are the refracting powers of the two lenses, and $\left(\frac{\mu-1}{\Delta n}\right)_1$ $\left(\frac{\mu-1}{\Delta n}\right)_2$ the relative dispersions of the two glasses in use. Let us take an example where the relative dispersions in two glasses are 43·3 and 36 respectively; the equation then becomes—

$$\frac{\varphi_1}{\varphi_2} = \frac{36}{43{\cdot}3} \text{ or } \varphi_1 = 0{\cdot}87\ \varphi_2$$

From this it will be seen that, by assuming the focus of one lens, we are able to find the focus that the correcting lens must have. I think it would be as well to mention that, owing to the fact that the dispersion of a glass is never proportional, the complete correction for achromatism is less simple than this would lead one to suppose, but for the purpose of illustration it is not at present necessary to further discuss this point. We saw that with a pair of lenses it was possible to correct for spherical aberration. The mathematical formula which must be satisfied in order to do so is by no means simple. I give it above without attempting to indicate the steps by which it is obtained. Any one interested in the matter will find it fully discussed in Herschel's "Light."

Suppose, now, we wish to make up a system of two lenses out of two given glasses, and to correct it for spherical and chromatic aberration by means of these formulæ. We will assume the focus of one lens, and from formula A for achromatism we shall obtain the focus of the second lens. We therefore know φ' φ'' and μ' μ''. What, then, are the unknown quantities in formula B? The four curvatures of the two lenses ρ' ρ'' ρ''' ρ''''.

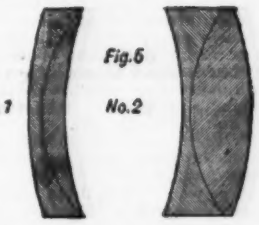
In the construction of photographic lenses we always endeavor to have as few reflecting surfaces as possible, in order that no large proportion of the light which enters a photographic lens may be reflected back again. Thus, in making an achromatic pair of lenses we endeavor to make one curve of each lens the same, and to cement the lenses together. That is to say, we make $\rho'' = \rho'''$. This considerably simplifies the equation (B). We have only three unknown quantities, and, moreover, we have from the following two equations connecting them—

$$(\mu' - 1)(\rho' - \rho'') = \varphi'. \qquad (\mu'' - 1)(\rho''' - \rho'''') = \varphi.$$

Thus we can reduce our formula to a form where only one unknown quantity exists. It is true it is an equation of considerable complexity, but when we have inserted the known quantities it is merely a matter of arithmetic to simplify it. Now arises a point of some interest. The solution of this equation will give us the shape of the lens that must be made in order to obtain a compound lens free from both spherical and chromatic aberration, and a lens for a shape that will not satisfy this equation will not be accurately corrected. It would therefore appear that for any two given kinds of glass the lens would have to be made of one particular shape and no other. But if we examine the expression in B more closely, we shall find that when simplified out it becomes a quadratic equation, and that it has in general two roots, that is to say, with most kinds of glass two shapes of lenses can be made, each of which will give perfect correction for spherical and chromatic aberration.

There are glasses which, however, we generally avoid, whose refraction indices and dispersions are such that the roots of the equation are imaginary, and we find that with these glasses it is impossible to obtain a system of this nature of any shape whatever that shall give a perfect correction for the aberrations. We shall find that in this case we must make lenses whose curves are not the same, which cannot therefore be cemented.

I have sketched the necessary shapes of the two forms of lens given by two kinds of glass which are in constant use, and it will be found that most of the glasses that have until recently been employed will give for their corrected lenses shapes that are more or less similar to the two forms figured.



It is interesting to note that the form No. 2 is that generally employed for telescopes, as the curves are less sensitive to slight alterations, while the shape No. 1 is that which is employed for a large number of photographic objectives, on account of properties which this form of lens possesses that I shall have again to allude to. In order to make this point more clear, I have sketched a series of lenses all made of the same two glasses, all corrected for achromatism, but in which only one is corrected, both for spherical as well as chromatic aberration.

There are many ways of combining the lenses so as to correct one or other of the aberrations, but, as we have seen, in general only two for correcting the two together.

We have, so far, only considered that bundle of rays which passes through the center of the lens, and forms the center of the picture; and, as we have shown, it is necessary, in order that this portion of the picture should be sharp, that there should be no spherical or chromatic aberration. The question next arises as to what method is employed in order to obtain sharp pictures at the margin of the photographic plate; that is to say, by what means a bundle of rays, passing through the lens obliquely, may be brought to a single point.

Now, a good plan, undoubtedly, would be to make a globe of glass, and use a spherical plate, except that the achromatism would be difficult to correct, and it would be difficult to use different apertures or stops. For it is evident that a bundle of rays passing through a globe would be affected in an exactly similar manner, whether they passed straight through or at an angle. But the globe is impracticable; it has been tried, and has been discarded, for many reasons.

FORMULA B.

$$0 = \left\{ \begin{array}{l} \frac{\phi'}{\mu'}\left\{(2 - 2\mu'^2 + \mu'^3)\rho'^3 + (\mu' + 2\mu'^2 - 2\mu'^3)\rho'\rho'' + \mu'^3\rho''^2\right\} \\ + \frac{\phi''}{\mu''}\left\{(2 - 2\mu''^2 + \mu''^3)\rho''^3 + (\mu'' + 2\mu''^2 - 2\mu''^3)\rho''\rho''' + \mu''^3\rho'''^2\right\} \\ - \frac{\phi'\phi''}{\mu''}\left\{(4 + 3\mu'' - 3\mu''^2)\rho''^2 + (\mu'' + 2\mu''^2)\rho''\right\} \\ + \frac{\phi'^2\phi''}{\mu''}\left\{2 + 3\mu''\right\} \end{array} \right\}$$

where ϕ', ϕ'' = refracting powers of two lenses, μ', μ'', = refractive indices of the two glasses.
ρ' ρ'' = curvatures of first lens, ρ'' ρ''' = curvatures of second lens.

Another plan, which would work equally well, is that the complete lens should be two portions of a hollow globe, of which the surfaces are concentric—thus. Here, also, you will observe the oblique rays would pass through a similar set of surfaces to the central rays, and, although a certain alteration would take place, we may say that, practically, the oblique rays would be refracted to a single point, provided central rays were refracted to one point.

Now, what are the ways in which opticians have hitherto corrected for the aberration of the oblique rays, which is called astigmatism? The globular lens was tried, and found unserviceable, and though hitherto the concentric lens has been an impossibility, we have reason to believe that in the future this form of lens will be made. The method of correcting for this astigmatism has been by making the lens as nearly as

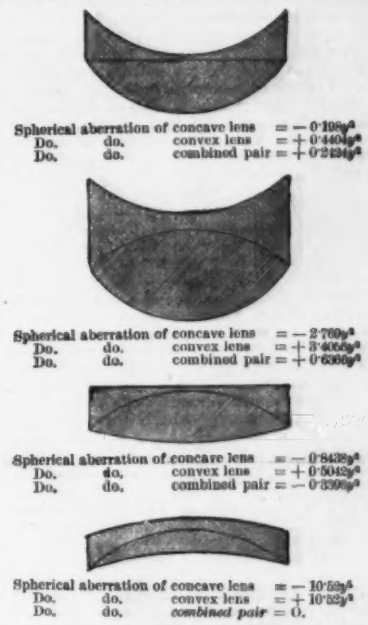

Spherical aberration of concave lens = − 0·198y³
Do. do. convex lens = + 0·4404y³
Do. do. combined pair = + 0·2424y³
Spherical aberration of concave lens = − 2·760y³
Do. do. convex lens = + 3·4056y³
Do. do. combined pair = + 0·6306y³
Spherical aberration of concave lens = − 0·8438y³
Do. do. convex lens = + 0·5042y³
Do. do. combined pair = − 0·3396y³
Spherical aberration of concave lens = − 10·52y³
Do. do. convex lens = + 10·52y³
Do. do. combined pair = 0.

FIG. 6.—SERIES OF ACHROMATIC COMBINATIONS, SHOWING DIFFERENT DEGREES OF ABERRATION.

possible of the concentric form. If it were quite concentric, the lens could not, with our usual glass, be made of the required refraction, so that we have been obliged to make lenses which are far from being concentric, but which, being made in the form of as deep meniscuses as we can make, somewhat approach the concentric form, and thus improve, but in no way annihilate, the astigmatism.

Let us suppose we are anxious to make a lens to cover a plate that subtends an angle of say 30° to 40°, and that shall have an aperture one-eighth of the focus. Suppose the focus of the lens be 10 inches, then the bundle of rays that enters the lens from any point of the object must be ⅛ or 1¼ inches. The lens cannot be smaller, therefore, than 1¼ inches, and it is found, for other reasons, that it must be at least 1⅛ inches. The deepest curve we can conveniently make of that diameter is say $\frac{5}{16}$ of an inch, or thereabout, and this limits the convexity of the meniscus that can be used.

Well, we know that in order to correct astigmatism we require the lenses to be as deep as possible, and as nearly parallel as possible, so we decide to have our lenses of such curves that the deepest is about $\frac{5}{16}$ inch. We decide to have a pair of symmetrical lenses, in order to have no distortion, and that they shall be placed in a position to give as nearly as possible the form of a hollow sphere. Now comes the point what glass shall be used. We observed before that with every two kinds of glass the lenses could only be made of two shapes. Thus, we must look through our glasses to see which pair will best give us this deep meniscus form. We shall find that for a lens of the type I have mentioned, the glasses known as light and heavy flint combined together will give the nearest approximation to the shape required. That is to say, in order to be able to make a lens with these very deep curves we must use two glasses, whose refractive indices and dispersions are unusually close together, otherwise the adequate corrections cannot be obtained. For a lens with a larger aperture than one-eighth of its focus the lenses must be larger; it is then no longer possible to employ so deep a curve as $\frac{5}{16}$ inch, as it would be more than a hemisphere and could not be made, and the curves must of necessity be of a flatter form. We must again look through the kinds of glass at our disposal, and we shall find that glasses with a greater difference between their refractive indices and dispersion must be selected.

This will have, I hope, indicated very roughly and briefly some of the general defects of a simple lens, which we, as opticians, endeavor to correct. For portrait lenses we devote ourselves beyond everything to the correction of the spherical and chromatic aberrations of the central rays, because large apertures are necessary in order to make the lenses rapid, and the larger the aperture the more the defects in the aberration show up. That is to say, in portrait lenses we devote ourselves to the central definition of the lens. In rapid and wide angle doublets, although the central aberrations must be carefully attended to, the corrections for astigmatism and distortion are the most important. Again, with single landscape lenses a certain amount of distortion is tolerated in order to obtain better marginal definition. In order to describe all the different details of construction, it would not require a single paper, but a series, and I doubt if any but opticians would be interested. I have been unable to touch this evening on many points of special interest.

The flare spot and its causes and modifications in various kinds of lenses would be a subject that, to be fully treated, would require considerable time. Wherever light meets a polished surface of glass a portion of the light is refracted and a portion is reflected, and thus with every lens a certain amount of light enters the camera which has not passed straight through the lens, but has been reflected backward and forward

from the various surfaces of the combination before entering the camera. The amount of this light is exceedingly small, compared with the body of light which passes through the lens, and if it is diffused over the whole of the photographic plate, it has no appreciable effect. It, however, sometimes happens in a carelessly adjusted lens, more usually of the doublet form, that the greater portion of this light thrown into the camera by internal reflections is concentrated upon one part of the plate, and forms a patch of light called the flare spot.

Another interesting point is the special chromatic correction which has to be made—owing to the irrationality of the spectrum—in order to make the focus coincident for the chemical and visual rays. In this connection, you will no doubt expect me to speak of the new optical glass which has recently been made at Jena. I think it has sometimes been supposed that the advantage that would be gained by the use of this glass for photographic objectives would be mainly due to the destruction of the secondary spectrum. I anticipate no improvement worth mentioning from this cause. Those who are familiar with that beautiful optical correction of a telescope object glass, and who have compared it with the correction of the best photographic objectives, which are purposely imperfectly corrected in that direction, will realize that the correction of the secondary spectrum is of very little consequence in the construction of photographic lenses. There are now being turned out from the glass factory at Jena over ninety kinds of glass, and some of these possess very remarkable qualities, such that I think it not impossible that we may be able to make in the future a doublet lens that is absolutely concentric, and in which the covering power is thereby largely increased. There are many serious difficulties in the way, and although the firm of which I am a member have been for many months working in this direction, the investigations are not yet sufficiently complete for me to be able to give you any definite information as to their results.

I will not to-night discuss the much debated point as to whether it is legitimate to leave a lens more or less imperfectly corrected for aberration in order to obtain the so-called "depth of focus." All such points as these may appear to be of secondary importance, but they must nevertheless be carefully considered in the construction of photographic lenses.

In concluding this paper, I hope I may be excused if I make one or two remarks on the methods of constructing optical instruments. When the principle of achromatism was discovered, the achromatic telescope was made by Dollond largely from practical experiments. The achromatic microscope was worked out by Lister and others by practical methods, and even at the present time many things are done in practice which are not even known of by theoretical men. I believe I am correct in saying that there is no book which gives a correct representation of a high power microscopic object glass, and most of the figures which are to be seen in books are entirely misleading.

There can be no doubt that in certain branches of optics the practical man formerly led the way, and it was only afterward that his methods were theoretically explained. This naturally produced among opticians a certain contempt for theoretical work, while the theoretical men were somewhat skeptical of the rule of thumb mode of inquiry often employed by the instrument maker.

Thus it comes to pass that we find in England, except in rare instances, very little combination of practical and theoretical men in the production of optical instruments. Practical men are realizing that, although the improvements that have in past years been made in optical instruments have been in a great measure due to the empirical method of inquiry, now that the science is more completely worked out, and the conditions have become less simple, the advances that will in future be made will undoubtedly be due more or less to theoretical research. Now we opticians are men of business, who have not only to make optical instruments, but also to make a living out of them, and have not so much time as we should like for theoretical work. What, then, is our annoyance when we find, on entering the study of the subject, that the books are now written, not that they may be of practical use, not that they may advance the science, but that the student may have simple formulæ and dodges to pass examinations. The pure mathematician is apt to be so impressed with the necessity of having a formula that is of a pretty and symmetrical form and easy to cram for examinations, that he sometimes arranges his signs and terms in a manner such that in order to make practical applications of the same, the formula has to be entirely reconstructed. Is it not a disgrace to our literature that in optical text books the thickness of a lens is generally neglected or merely mentioned as a corollary? It is only within the last year or so that any accessible English book has treated adequately of aberration since the time of Herschel. The investigation of oblique pencils is generally left almost untouched, and the question of signs is in a chaotic condition. If theoretical men will combine with us practical men by writing books by which we can educate ourselves in the direction we require, there are many improvements in optical instruments which, in the not distant future, we may hope to accomplish.

THE ORIGIN OF THE NAME "AMERICA."

The bulletin of the Paris Geographical Society which has just been issued contains an account by M. Jules Marcon of certain further researches which he has made into the origin of the name "America." As far back as 1875 he published a paper on the same topic which attracted much attention at the time, and he has since devoted much labor to an investigation of early historical documents in which the new world is named. The popular notion that America was so called from the Christian name of Amerigo Vespucci is, he says, wholly unfounded, and he sums up his conclusions in this way: 1. Amerique is the Indian name of the mountains between Juigalpa and Libertad, in the province of Chontales, which separate Lake Nicaragua from the Mosquito coast. The word in the Maya language signifies "the windy country," or "the country where the wind blows always." 2. The Christian name of Vespucci was Alberico in Italian and Spanish, Albericus in Latin. 3. This particular name is subject to an enormous number of variations, as the nomenclature and calendars of Italian and Spanish saints of the period show; but nowhere is there any such variation as Americus, Amerrigo, Amergio, Almerigo, etc., and none of these is either a diminutive or a variation in use in Italy, Spain, or France for Alberico or Albert. 4. Before 1507, when Jean Basin, of Saint Die, published the name, it is not to be found in any printed document, nor even in any manuscript of recognized and incontestable authority. Mr. Marcon claims that his theory of a native origin for the name America has been accepted in Spain, Spanish America, and, with some exceptions, in the United States; in France, Germany, and Italy it has excited doubt and surprise, but in the last-named he has the support of the eminent Turin geographer M. Guido Cora. There is no doubt that Columbus and Vespucci went along the Mosquito coast at the feet of the Sierra Amerrique, and that the name was reported by the officers and men of these expeditions; and Schoner, the geographer, declared in 1515 that the name was already popular in Europe. It is beyond question that one edition of Vespucci's letter on his third voyage has the name Amerigo in the place of the Christian name; 19 editions had Albericus, and subsequent Italian editions had Alberico. The one with Amerigo on the title page was published in 1506, but M. Marcon suggests that this was never intended to be a variation of Alberico, but rather the adaptation of Amerrique, a name already known and applied to the New World, to Vespucci's name to distinguish him, as we say now "Chinese Gordon," to distinguish the particular Gordon by suggesting one of his greatest feats. The paper, which is very learned concerning the geography and geographical publications of the 16th century, is not yet concluded.

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